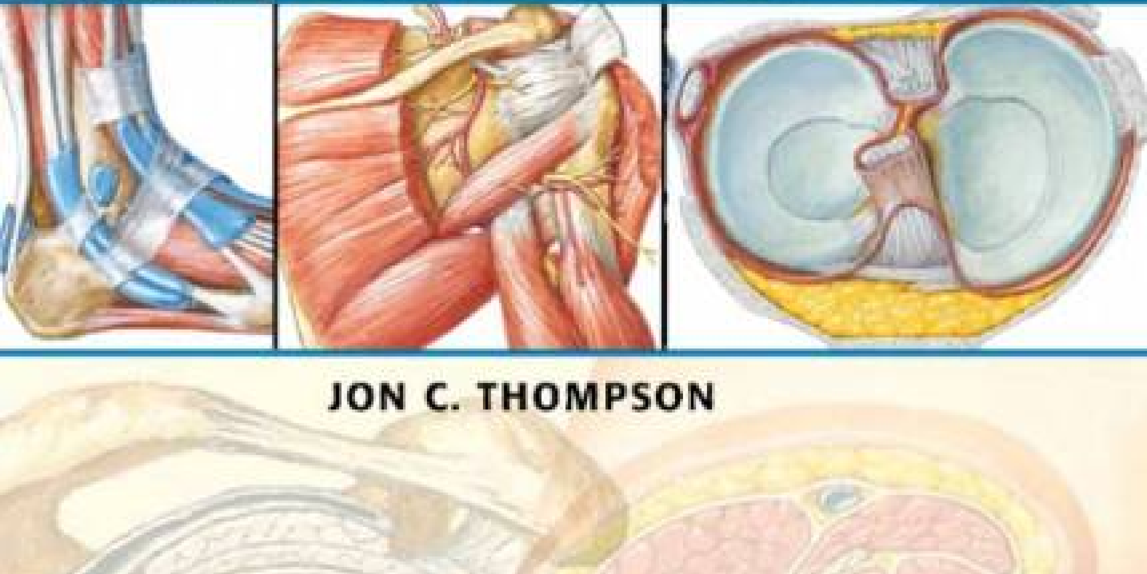
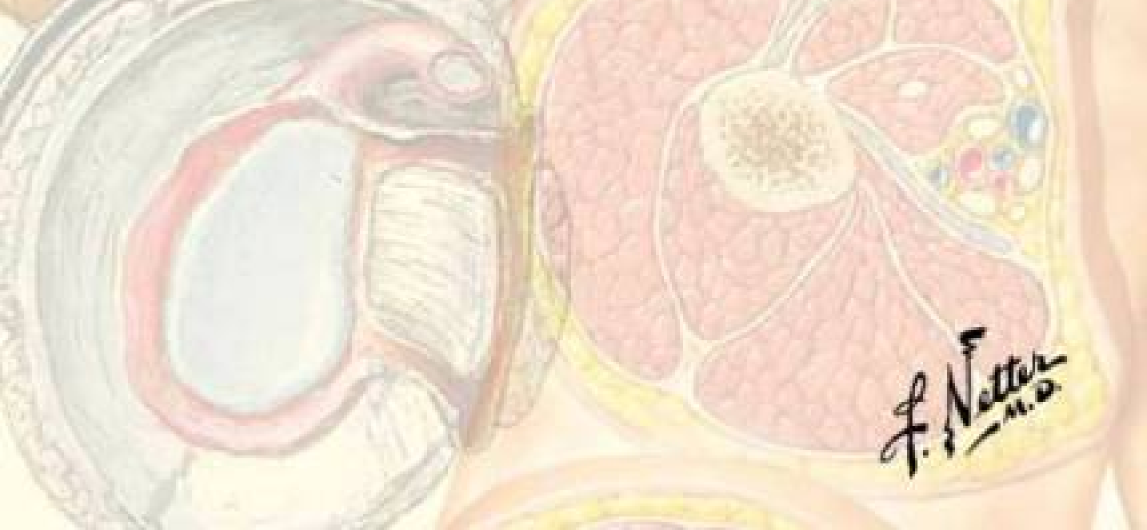
Netter's CONCISE ORTHOPAEDIC ANATOMY

2nd edition



JON C. THOMPSON



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Preface

I suppose there is always a question regarding the reception a first edition of any text will receive before its publication. The response and enthusiasm for the first edition of this text have been rewarding and exceeded my optimistic expectations. Inasmuch as imitation is a form of flattery, I am also pleased with the development of multiple other titles in the *Netter's Concise* series that were based on the format of this text. Despite this encouragement, it quickly became clear that the first edition of this text, written predominantly while I was a medical student, was in need of an update. Although the anatomy is a constant, our understanding of it, our terminology, and its clinical application continue to advance.

I received considerable feedback, both positive and negative, on the first edition. Much of it was constructive, and I am grateful for all of it. The revision has been both challenging and rewarding. Formatting this enormous volume of material was a painstaking process, and I would like to thank John Casey, the production team, and all of those at Elsevier for their patience, hard work, and professionalism. With their help I was able to develop my vision of this project. It has been a pleasure to work with them.

In this revision, I have tried to strike a balance between being thorough and yet concise while staying true to the original concept of the text, which was to allow the incomparable Netter artwork to do a majority of the teaching. Knowing it's impossible to please everyone, I look forward to hearing how well the balance was or was not achieved.

In this second edition, every table, both anatomic and clinical, was updated or revised. We were also able to enhance the text with radiographs, additional sections, and new artwork including additional surgical approaches. In the preface to the first edition I noted that the text embodied the book that I unsuccessfully tried to find on the shelves of medical bookstores as a medical student. That failed search originally prompted me to write the text. With the above-mentioned updates and additions, I feel that statement should be amended. *This* edition is, in fact, the text for which I had originally searched and fulfills the vision of the initial undertaking that began over 10 years ago. I hope the readers find it so.

Jon C. Thompson, MD

About the Author

Jon C. Thompson, MD, received his undergraduate degree from Dartmouth College and his medical degree from the Uniformed Services University of the Health Sciences in Bethesda, Maryland. Having recently completed his orthopaedic residency at Brooke Army Medical Center in San Antonio, Texas, he is now board certified in orthopaedic surgery and sports medicine. He is currently continuing his military service at Irwin Army Community Hospital, Fort Riley, Kansas. Dr. Thompson is glad to no longer have to answer questions regarding why he published an orthopaedic text before doing any formal orthopaedic training, as well as being able to spend more time with his family. His wife and four young children, though very supportive, are not looking forward to Dr. Thompson's future publishing projects.

To the men and women of the armed forces
who bravely serve our country

To the readers
whose enthusiasm for the text has
motivated me to do better

To my children,
Taylor, Turner, Jax, and Judson,
constant and perfect reminders
of the truly important and joyful aspects of life

To my wife,
Tiffany, the foundation
of every good thing in my life

About the Artists

Frank H. Netter, MD

Frank H. Netter was born in 1906, in New York City. He studied art at the Art Student's League and the National Academy of Design before entering medical school at New York University, where he received his medical degree in 1931. During his student years, Dr. Netter's notebook sketches attracted the attention of the medical faculty and other physicians, allowing him to augment his income by illustrating articles and textbooks. He continued illustrating as a sideline after establishing a surgical practice in 1933, but he ultimately opted to give up his practice in favor of a full-time commitment to art. After service in the United States Army during World War II, Dr. Netter began his long collaboration with the CIBA Pharmaceutical Company (now Novartis Pharmaceuticals). This 45-year partnership resulted in the production of the extraordinary collection of medical art so familiar to physicians and other medical professionals worldwide.

In 2005, Elsevier, Inc., purchased the Netter Collection and all publications from Icon Learning Systems. There are now over 50 publications featuring the art of Dr. Netter available through Elsevier, Inc. (in the US: www.us.elsevierhealth.com/Netter and outside the US: www.elsevierhealth.com)

Dr. Netter's works are among the finest examples of the use of illustration in the teaching of medical concepts. The 13-volume *Netter Collection of Medical Illustrations,* which includes the greater part of the more than 20,000 paintings created by Dr. Netter, became and remains one of the most famous medical works ever published. *The Netter Atlas of Human Anatomy,* first published in 1989, presents the anatomical paintings from the Netter Collection. Now translated into 16 languages, it is the anatomy atlas of choice among medical and health professions students the world over.

The Netter illustrations are appreciated not only for their aesthetic qualities, but also, more important, for their intellectual content. As Dr. Netter wrote in 1949, ". . . clarification of a subject is the aim and goal of illustration. No matter how beautifully painted, how delicately and subtly rendered a subject may be, it is of little value as a *medical illustration* if it does not serve to make clear some medical point." Dr. Netter's planning, conception, point of view, and approach are what inform his paintings and what makes them so intellectually valuable.

Frank H. Netter, MD, physician and artist, died in 1991.

Learn more about the physician-artist whose work has inspired the Netter Reference collection:

http://www.netterimages.com/artist/netter.htm

Carlos Machado, MD

Carlos Machado was chosen by Novartis to be Dr. Netter's successor. He continues to be the main artist who contributes to the Netter collection of medical illustrations.

Self-taught in medical illustration, cardiologist Carlos Machado has contributed meticulous updates to some of Dr. Netter's original plates and has created many paintings of his own in the style of Netter as an extension of the Netter collection. Dr. Machado's photorealistic expertise and his keen insight into the physician/patient relationship informs his vivid and unforgettable visual style. His dedication to researching each topic and subject he paints places him among the premier medical illustrators at work today.

Learn more about his background and see more of his art at:

http://www.netterimages.com/artist/machado.htm

Introduction

Netter's Concise Orthopaedic Anatomy is an easy-to-use reference and compact atlas of orthopaedic anatomy for students and clinicians. Using images from both the *Atlas of Human Anatomy* and the 13-volume *Netter Collection of Medical Illustrations,* this book brings over 450 Netter images together.

Tables are used to highlight the Netter images and offer key information on bones, joints, muscles, nerves, and surgical approaches. Clinical material is presented in a clear and straightforward manner with emphasis on trauma, minor procedures, history and physical exam, and disorders.

Users will appreciate the unique color-coding system that makes information look-up even easier. Key material is presented in black, red, and green to provide quick access to clinically relevant information.

BLACK: standard text

GREEN: key/testable information

RED: key information that if missed could result in morbidity or mortality

CHAPTER 1

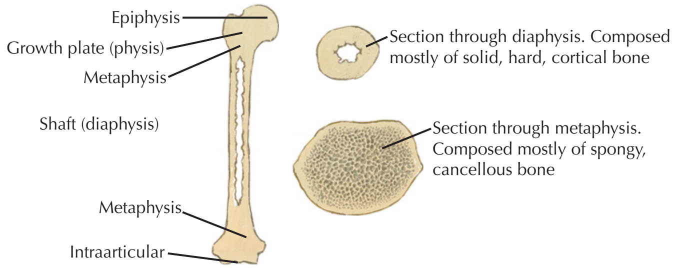
Basic Science

Bones 2

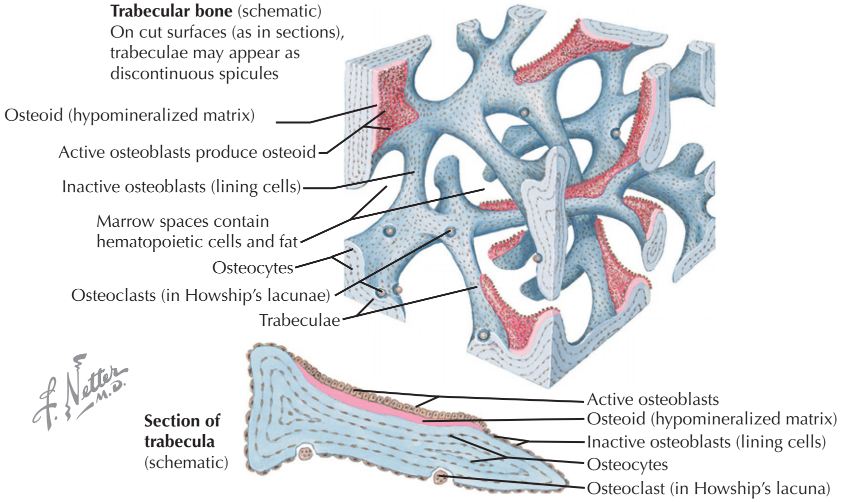
Joints 16

Nerves 22

Muscles 24

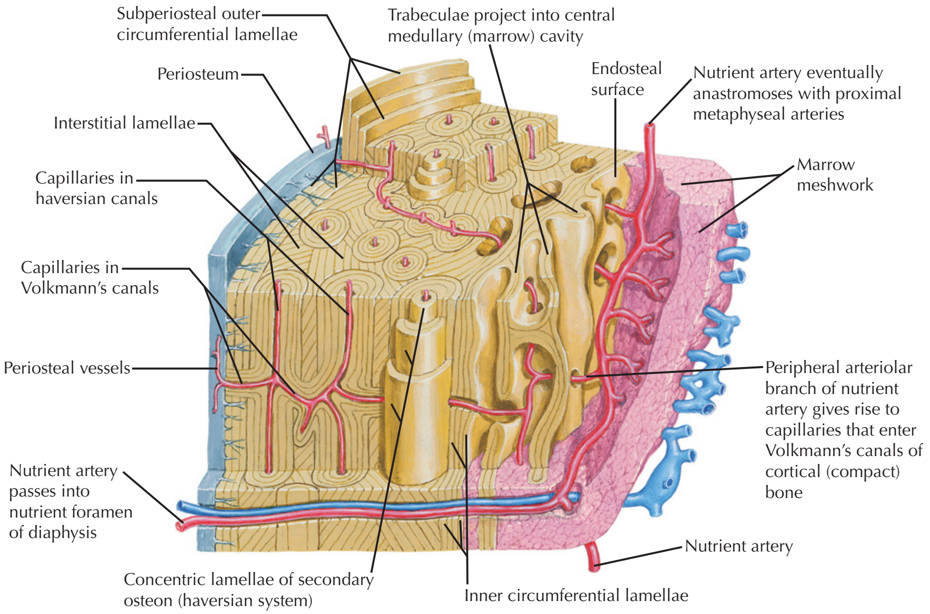

Epiphysis
Growth plate (physis)
Metaphysis
Shaft (diaphysis)
Metaphysis
Intraarticular
Section through diaphysis. Composed mostly of solid, hard, cortical bone
Section through metaphysis. Composed mostly of spongy, cancellous bone

Structure of Cancellous Bone


Trabecular bone (schematic)
On cut surfaces (as in sections), trabeculae may appear as discontinuous spicules
Osteoid (hypomineralized matrix)
Active osteoblasts produce osteoid
Inactive osteoblasts (lining cells)
Marrow spaces contain hematopoietic cells and fat
Osteocytes
Osteoclasts (in Howship's lacunae)
Trabeculae
F. Netter M.D.
Section of trabecula (schematic)
Active osteoblasts
Osteoid (hypomineralized matrix)
Inactive osteoblasts (lining cells)
Osteocytes
Osteoclast (in Howship's lacuna)

STRUCTURE	COMMENT
	BONE
Function	• Serves as attachment sites for muscles • Protection for organs (e.g., cranium, ribs, pelvis) • Reservoir for minerals in the body: 99% of body's calcium stored as hydroxyapatite crystals • Hematopoiesis site
	BONE FORMS
Long bones	• Form by enchondral ossification (except clavicle): primary (in shaft) and secondary growth centers • Have physes ("growth plates") at each end where it grows in length (metacarpals, metatarsals, and phalanges of hand and feet typically have only one physis) • 3 parts of long bone: ◦ **Diaphysis:** shaft, made of thick cortical bone, filled with bone marrow ◦ **Metaphysis:** widening of bone near the end, typically made of cancellous bone ◦ **Epiphysis:** end (usually articular) of bone, forms from secondary ossification centers
Flat bones	• Form by intramembranous ossification (e.g., pelvis, scapula)
	MICROSCOPIC BONE TYPES
Woven	• Immature or pathologic bone; poorly organized, not stress oriented • Examples: Immature—bones in infants, fracture callus; Pathologic—tumors
Lamellar	• Mature bone; highly organized with stress orientation • Mature (>4y.o.) cortical and cancellous bone are both made up of lamellar bone

Structure of Cortical (Compact) Bone


Subperiosteal outer circumferential lamellae
Trabeculae project into central medullary (marrow) cavity
Periosteum
Endosteal surface
Nutrient artery eventually anastromoses with proximal metaphyseal arteries
Interstitial lamellae
Capillaries in haversian canals
Marrow meshwork
Capillaries in Volkmann's canals
Periosteal vessels
Peripheral arteriolar branch of nutrient artery gives rise to capillaries that enter Volkmann's canals of cortical (compact) bone
Nutrient artery passes into nutrient foramen of diaphysis
Nutrient artery
Concentric lamellae of secondary osteon (haversian system)
Inner circumferential lamellae

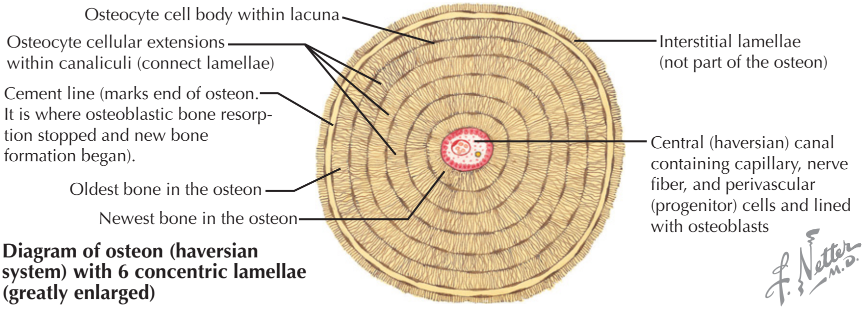
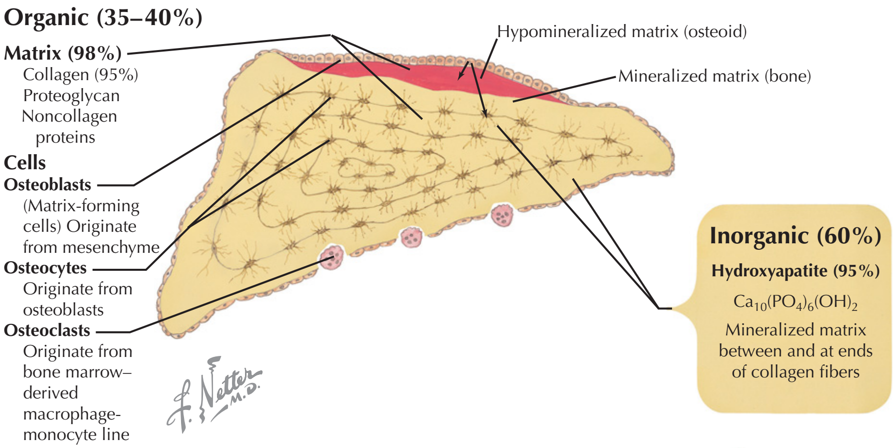
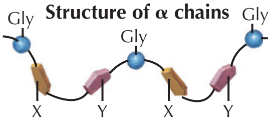

Osteocyte cell body within lacuna
Osteocyte cellular extensions within canaliculi (connect lamellae)
Interstitial lamellae (not part of the osteon)
Cement line (marks end of osteon. It is where osteoblastic bone resorption stopped and new bone formation began).
Central (haversian) canal containing capillary, nerve fiber, and perivascular (progenitor) cells and lined with osteoblasts
Oldest bone in the osteon
Newest bone in the osteon
F. Netter M.D.

Diagram of osteon (haversian system) with 6 concentric lamellae (greatly enlarged)

STRUCTURE	COMMENT
	STRUCTURAL BONE TYPES
Cortical (compact)	• Strong, dense bone, makes up 80% of the skeleton • Composed of multiple osteons (haversian systems) with intervening interstitial lamellae • **Osteons** are made up of concentric bone lamellae with a central canal (haversian canal) containing osteoblasts (new bone formation) and an arteriole supplying the osteon. Lamellae are connected by canaliculi. Cement lines mark outer limit of osteon (bone resorption ended). • Volkmann's canals: radially oriented, have arteriole, and connect adjacent osteons • Thick cortical bone is found in the diaphysis of long bones
Cancellous (spongy/trabecular)	• Crossed lattice structure, makes up 20% of the skeleton • High bone turnover rate. Bone is resorbed by osteoclasts in Howship's lacunae and formed on the opposite side of the trabeculae by osteoblasts. • Osteoporosis is common in cancellous bone, making it susceptible to fractures (e.g., vertebral bodies, femoral neck, distal radius, tibial plateau). • Commonly found in the metaphysis and epiphysis of long bones


Organic (35–40%)
Matrix (98%)
Collagen (95%)
Proteoglycan
Noncollagen proteins
Cells
Osteoblasts
(Matrix-forming cells) Originate from mesenchyme
Osteocytes
Originate from osteoblasts
Osteoclasts
Originate from bone marrow–derived macrophage-monocyte line
Hypomineralized matrix (osteoid)
Mineralized matrix (bone)
Inorganic (60%)
Hydroxyapatite (95%)
$Ca_{10}(PO_4)_6(OH)_2$
Mineralized matrix between and at ends of collagen fibers
F. Netter M.D.

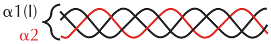
Structure of α chains


Gly
Gly
Gly
X
Y
X
Y

Each α chain comprises about 1,000 amino acids. Every third amino acid in chain is glycine, smallest of amino acids.

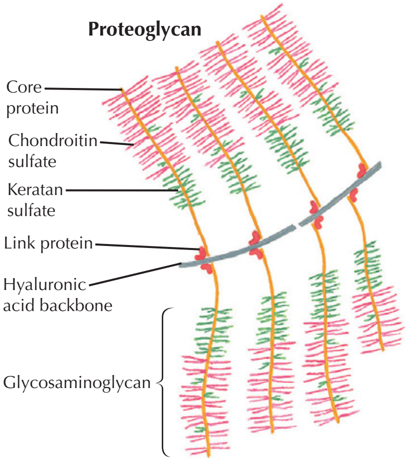
Collagen
(based on a chain composition of fibrils)

Type I



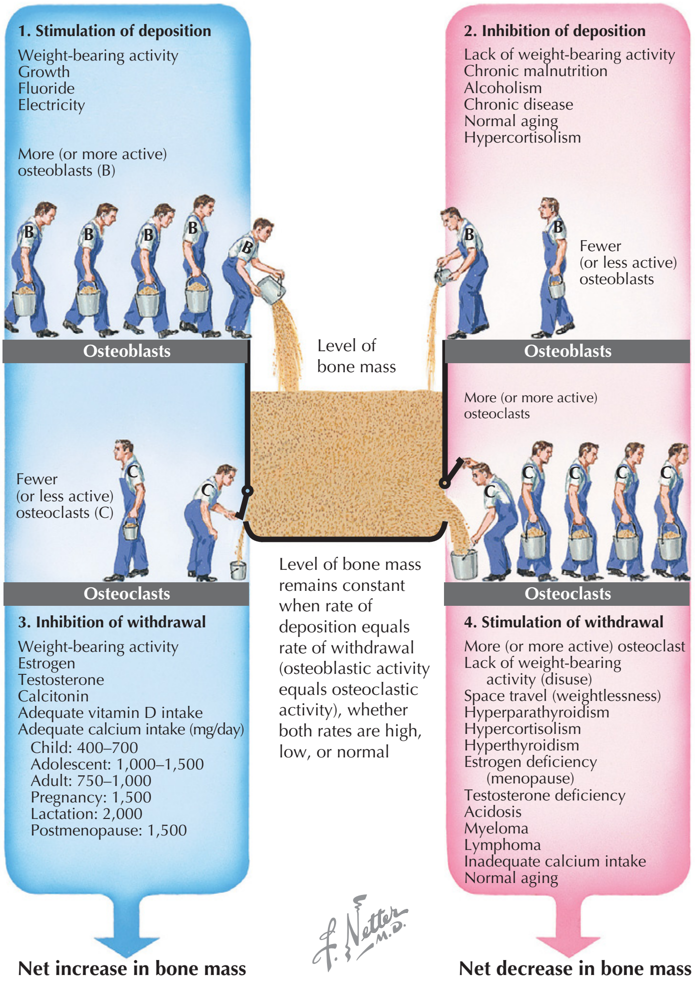
Two α1(I) chains and one α2 chain 5 $(\alpha1[I])_2\ \alpha2$; in bone, tendon, ligament.

Proteoglycan


Core protein
Chondroitin sulfate
Keratan sulfate
Link protein
Hyaluronic acid backbone
Glycosaminoglycan

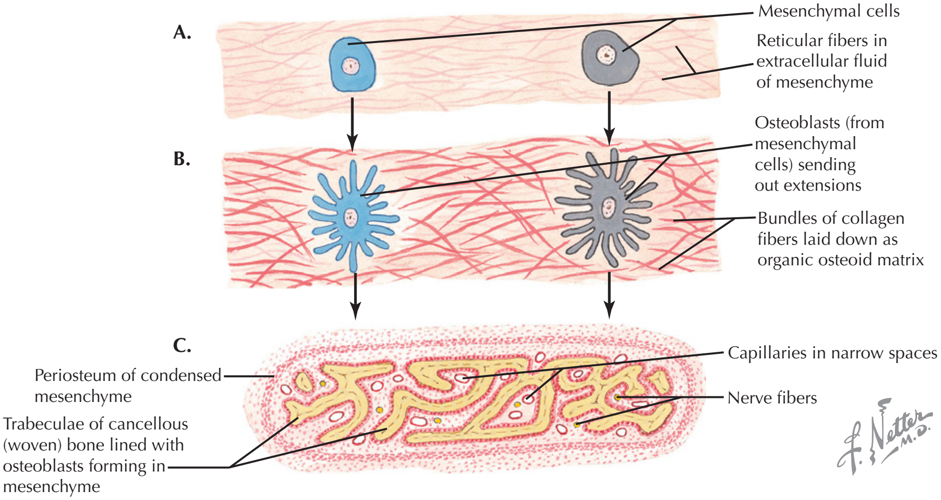
COMPONENT	COMMENT
BONE COMPOSITION	
Bone is composed of multiple components: 1. Organic phase ("matrix:" proteins, macromolecules, cells); 2. Inorganic phase (minerals, e.g., Ca^{++}); 3. Water	
Inorganic phase • Calcium hydroxyapatite • Osteocalcium phosphate	• Approximately 60% of bone weight • $Ca_{10}(PO_4)_6(OH)_2$. Primary mineral in bone. Adds compressive strength. • "Brushite" is a secondary/minor mineral in bone.
Organic phase • Collagen	• Also known as "osteoid" before its mineralization; approximately 35% of bone weight • Type 1 collagen gives tensile strength and is 90% of organic phase. Mineralization occurs at ends (hole zones) and along sides (pores) of the collagen fibers.
• Proteoglycans	• Macromolecules made up of a hyaluronic backbone w/ multiple glycosaminoglycans • Glycosaminoglycans (GAG): made of core protein w/ chondroitin & keratin branches • Gives bone compressive strength
• Noncollagen proteins	• Osteocalcin #1, is indicator of increased bone turnover (e.g., Paget's disease) • Others: osteonectin, osteopontin
• Cells	• Osteoblasts, osteocytes, osteoclasts
Water	• Approximately 5% of bone weight (varies with age and location)
Periosteum surrounds the bone, is thicker in children, and responsible for the growing diameter (width) of long bones.	

Four Mechanisms of Bone Regulation

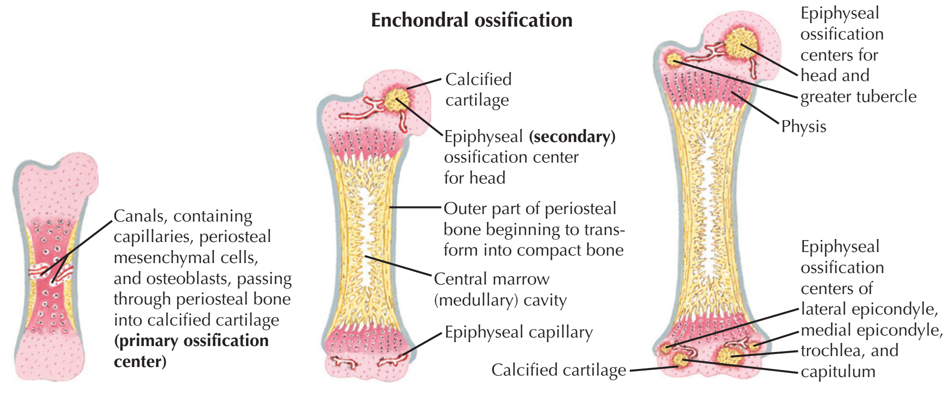

1. Stimulation of deposition
Weight-bearing activity
Growth
Fluoride
Electricity
More (or more active) osteoblasts (B)
B
Osteoblasts
Fewer (or less active) osteoclasts (C)
C
Osteoclasts
3. Inhibition of withdrawal
Weight-bearing activity
Estrogen
Testosterone
Calcitonin
Adequate vitamin D intake
Adequate calcium intake (mg/day)
Child: 400–700
Adolescent: 1,000–1,500
Adult: 750–1,000
Pregnancy: 1,500
Lactation: 2,000
Postmenopause: 1,500
Net increase in bone mass
Level of bone mass
Level of bone mass remains constant when rate of deposition equals rate of withdrawal (osteoblastic activity equals osteoclastic activity), whether both rates are high, low, or normal
2. Inhibition of deposition
Lack of weight-bearing activity
Chronic malnutrition
Alcoholism
Chronic disease
Normal aging
Hypercortisolism
Fewer (or less active) osteoblasts
Osteoblasts
More (or more active) osteoclasts
Osteoclasts
4. Stimulation of withdrawal
More (or more active) osteoclast
Lack of weight-bearing activity (disuse)
Space travel (weightlessness)
Hyperparathyroidism
Hypercortisolism
Hyperthyroidism
Estrogen deficiency (menopause)
Testosterone deficiency
Acidosis
Myeloma
Lymphoma
Inadequate calcium intake
Normal aging
Net decrease in bone mass

CELL	COMMENT
BONE CELL TYPES	
Osteoblasts	• Function: produce bone matrix ("osteoid"). Make type 1 collagen and other matrix proteins • Line new bone surfaces and follow osteoclasts in cutting cones • Receptors: **PTH** (parathyroid hormone), vitamin D, glucosteroids, estrogen, PGs, ILs
Osteocytes	• Osteoblast surrounded by bone matrix. Represent 90% of all bone cells • Function: maintain & preserve bone. Long cell processes communicate via canaliculi. • Receptors: **PTH** (release calcium), **calcitonin** (do not release calcium)
Osteoclasts	• Large, multinucleated cells derived from the same line of cells as monocytes & macrophages • Function: when active, use a "ruffled border" to resorb bone; found in Howship's lacunae • Receptors: **calcitonin,** estrogen, IL-1, RANK L. Inhibited by bisphosphonates

Intramembranous ossification


A.
Mesenchymal cells
Reticular fibers in extracellular fluid of mesenchyme
B.
Osteoblasts (from mesenchymal cells) sending out extensions
Bundles of collagen fibers laid down as organic osteoid matrix
C.
Periosteum of condensed mesenchyme
Trabeculae of cancellous (woven) bone lined with osteoblasts forming in mesenchyme
Capillaries in narrow spaces
Nerve fibers
F. Netter M.D.

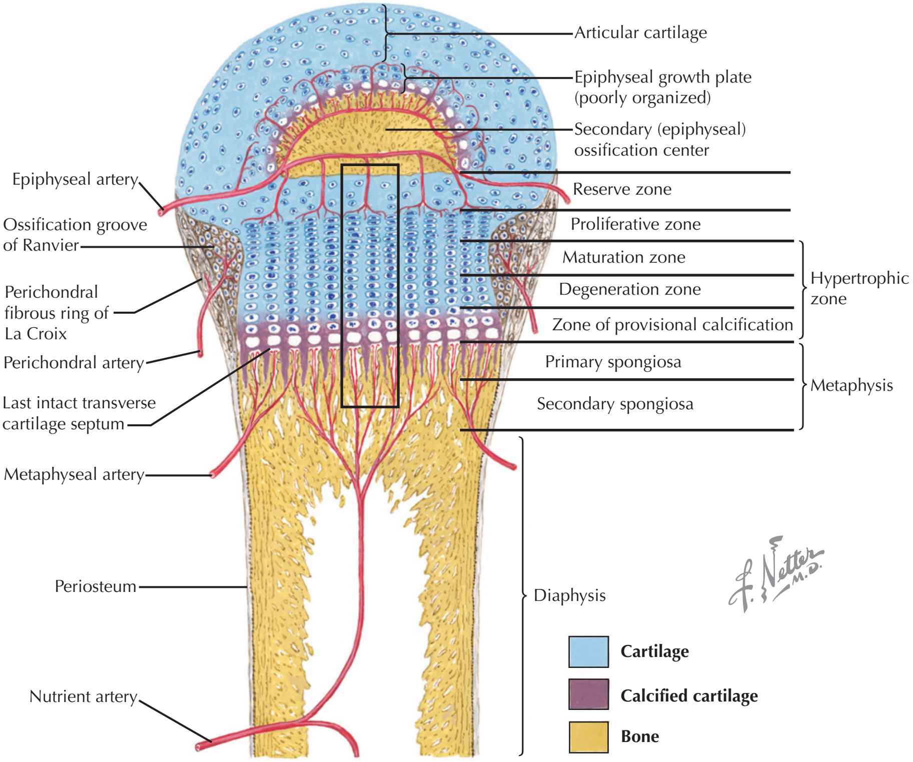
Enchondral ossification


Canals, containing capillaries, periosteal mesenchymal cells, and osteoblasts, passing through periosteal bone into calcified cartilage **(primary ossification center)**
Calcified cartilage
Epiphyseal **(secondary)** ossification center for head
Outer part of periosteal bone beginning to transform into compact bone
Central marrow (medullary) cavity
Epiphyseal capillary
Calcified cartilage
Epiphyseal ossification centers for head and greater tubercle
Physis
Epiphyseal ossification centers of lateral epicondyle, medial epicondyle, trochlea, and capitulum

At 9 weeks **At birth** **At 5 years**

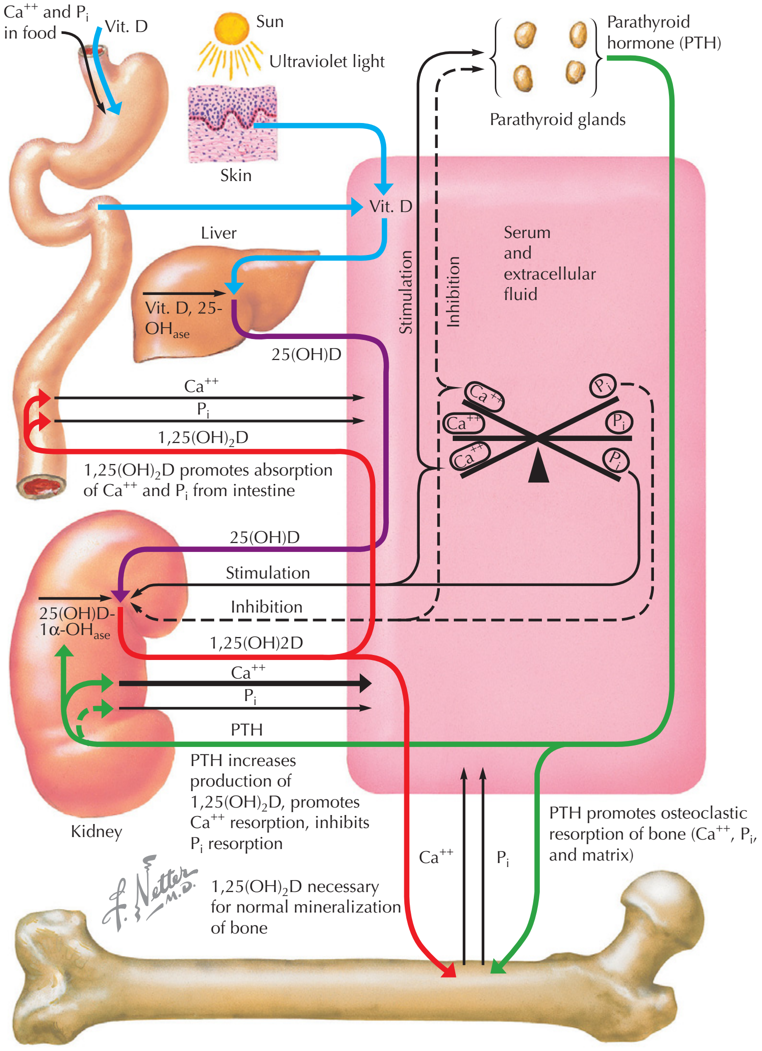
OSSIFICATION	COMMENT
BONE FORMATION	
Bone formation (ossification) occurs in 3 different ways: enchondral, intramembranous, appositional	
Enchondral	• Bone replaces a cartilage anlage (template). Osteoclasts remove the cartilage, and osteoblasts make the new bone matrix, which is then mineralized. • Typical in long bones (except clavicle). • Primary ossification centers (in shaft) typically develop in prenatal period. • Secondary ossification centers occur at various times after birth, usually in the epiphysis. • Longitudinal growth at the physis also occurs by enchondral ossification. • Also found in fracture callus
Intramembranous	• Bone develops directly from mesenchymal cells without a cartilage anlage. • Mesenchymal cells differentiate into osteoblasts, which produce bone. • Examples: flat bones (e.g., the cranium) and clavicle
Appositional	• Osteoblasts make new matrix/bone on top of existing bone. • Example: periosteal-mediated bone diameter (width) growth in long bones

Epiphysis and Physis


Articular cartilage
Epiphyseal growth plate (poorly organized)
Secondary (epiphyseal) ossification center
Epiphyseal artery
Reserve zone
Ossification groove of Ranvier
Proliferative zone
Maturation zone
Perichondral fibrous ring of La Croix
Degeneration zone
Hypertrophic zone
Zone of provisional calcification
Perichondral artery
Primary spongiosa
Metaphysis
Last intact transverse cartilage septum
Secondary spongiosa
Metaphyseal artery
Periosteum
Diaphysis
Nutrient artery
Cartilage
Calcified cartilage
Bone

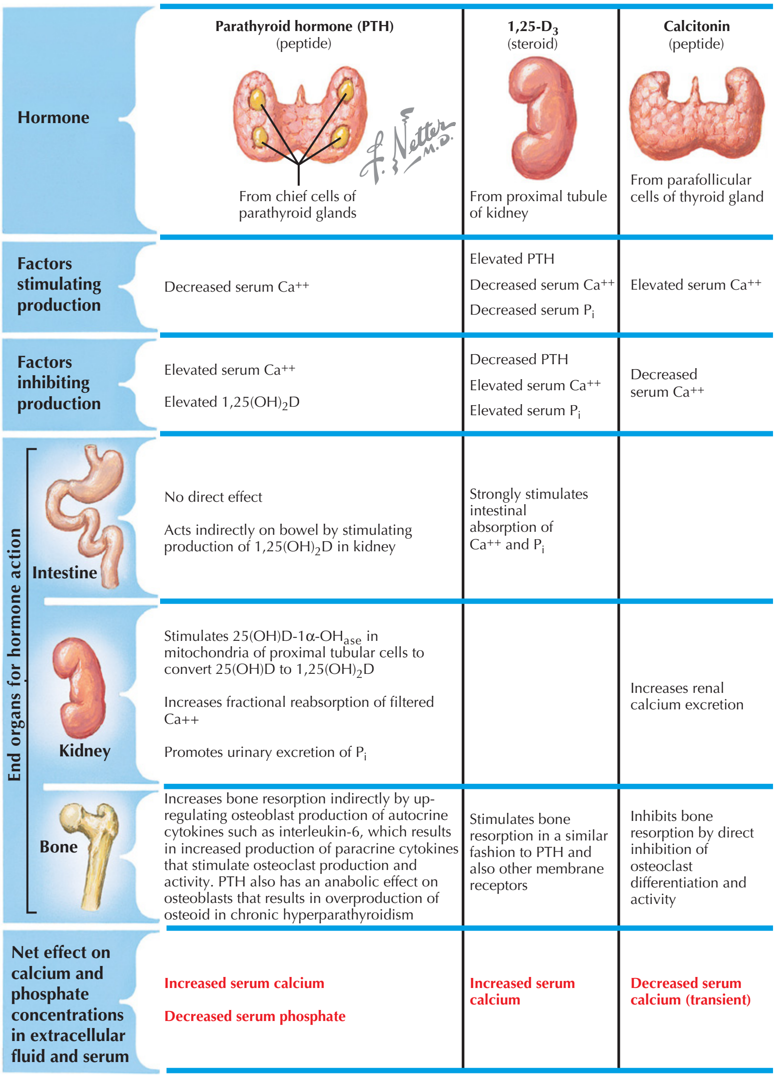
STRUCTURE	**COMMENT**
ANATOMY OF THE PHYSIS	
The physis provides longitudinal growth in long bones. It is divided into multiple zones, each with a different function. • There is another physis in each epiphysis (similar organization) responsible for epiphyseal growth (not longitudinal). • There is typically also a physis at the site of an immature apophysis (e.g., tibial tubercle). It fuses at bone maturity.	
Reserve zone	• Loosely organized cells produce abundant matrix and store metabolites.
Proliferative zone	• Longitudinal growth occurs here as chondrocytes divide and stack into columns. • Achondroplasia is result of dysfunction of this zone.
Hypertrophic zone Maturation zone Degenerative zone Zone of provisional Ca^{++}	• Has 3 subzones. Function is to prepare the matrix for calcification and calcify it. • Cells (chondrocytes) mature and enlarge 5-10x in size. • Chondrocytes die, proteoglycans are degraded, allowing for mineralization of matrix. • Released calcium mineralizes the cartilage matrix (radiographically dense zone).
Metaphysis Primary spongiosa Secondary spongiosa	• Osteoblasts make immature (woven) bone on the calcified cartilage. • Osteoclasts remove cartilage & immature bone; osteoblasts make new (lamellar) bone.
Other Groove of Ranvier Perichondral ring	• Peripheral chondrocytes allow for widening/growth of the physis. • AKA "perichondral ring of La Croix." Provides peripheral support for cartilaginous physis.

Normal Calcium and Phosphate Metabolism


Ca^{++} and P$_i$ in food
Vit. D
Sun
Ultraviolet light
Parathyroid hormone (PTH)
Parathyroid glands
Skin
Vit. D
Liver
Vit. D, 25-OH$_{ase}$
Stimulation
Inhibition
Serum and extracellular fluid
25(OH)D
Ca^{++}
P$_i$
1,25(OH)$_2$D
Ca^{++}
Ca^{++}
Ca^{++}
P$_i$
P$_i$
P$_i$
1,25(OH)$_2$D promotes absorption of Ca^{++} and P$_i$ from intestine
25(OH)D
Stimulation
25(OH)D-1α-OH$_{ase}$
Inhibition
1,25(OH)2D
Ca^{++}
P$_i$
PTH
PTH increases production of 1,25(OH)$_2$D, promotes Ca^{++} resorption, inhibits P$_i$ resorption
Kidney
Ca^{++}
P$_i$
PTH promotes osteoclastic resorption of bone (Ca^{++}, P$_i$, and matrix)
1,25(OH)$_2$D necessary for normal mineralization of bone
F. Netter M.D.

MINERAL	COMMENT
BONE METABOLISM	
Bone plays a critical role in maintaining proper serum calcium and phosphate levels.	
Calcium	• Calcium (Ca^{++}) plays a critical role in cardiac, skeletal muscle, and nerve function. • Normal dietary requirement 500-1300mg. More is required during pregnancy, lactation, fractures. • 99% of body's stored calcium is in the bone. • Calcium levels directly regulated by PTH and Vitamin D 1,25.
Phosphate	• Important component of bone mineral (hydroxyapatite) and body metabolic functions • 85% of body's stored phosphate is in the bone.

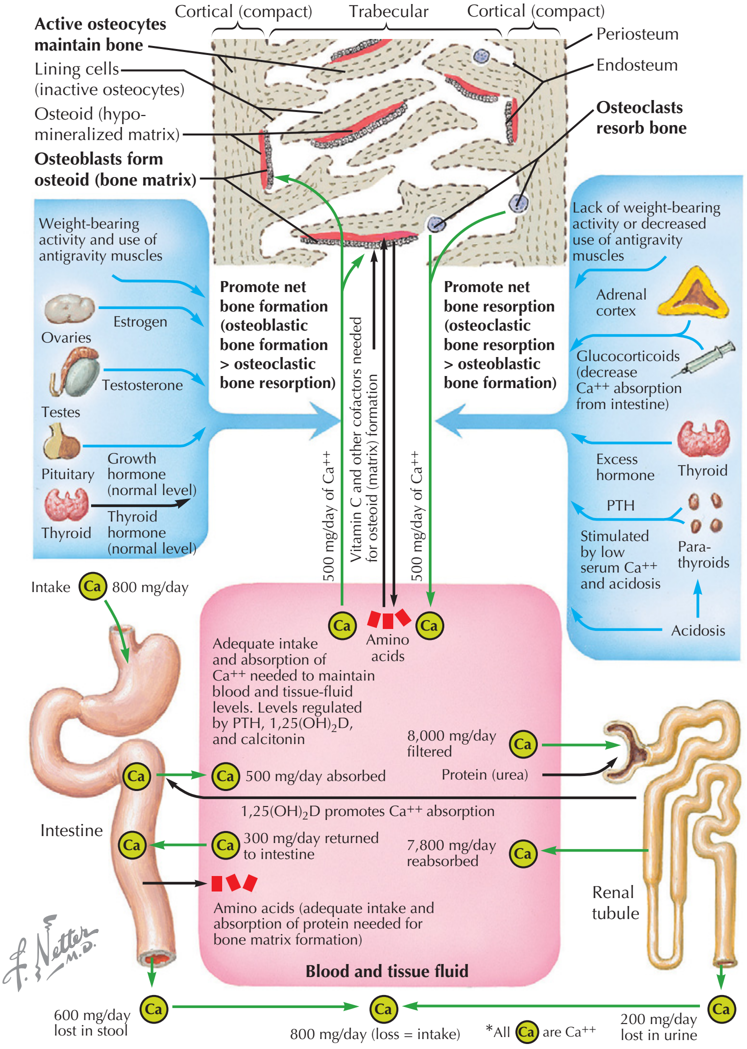
Regulation of Calcium and Phosphate Metabolism



	Parathyroid hormone (PTH) (peptide) From chief cells of parathyroid glands	**1,25-D_3** (steroid) From proximal tubule of kidney	**Calcitonin** (peptide) From parafollicular cells of thyroid gland
Hormone			
Factors stimulating production	Decreased serum Ca^{++}	Elevated PTH Decreased serum Ca^{++} Decreased serum P_i	Elevated serum Ca^{++}
Factors inhibiting production	Elevated serum Ca^{++} Elevated $1,25(OH)_2D$	Decreased PTH Elevated serum Ca^{++} Elevated serum P_i	Decreased serum Ca^{++}
End organs for hormone action — **Intestine**	No direct effect Acts indirectly on bowel by stimulating production of $1,25(OH)_2D$ in kidney	Strongly stimulates intestinal absorption of Ca^{++} and P_i	
Kidney	Stimulates $25(OH)D$-1α-OH_{ase} in mitochondria of proximal tubular cells to convert $25(OH)D$ to $1,25(OH)_2D$ Increases fractional reabsorption of filtered Ca^{++} Promotes urinary excretion of P_i		Increases renal calcium excretion
Bone	Increases bone resorption indirectly by up-regulating osteoblast production of autocrine cytokines such as interleukin-6, which results in increased production of paracrine cytokines that stimulate osteoclast production and activity. PTH also has an anabolic effect on osteoblasts that results in overproduction of osteoid in chronic hyperparathyroidism	Stimulates bone resorption in a similar fashion to PTH and also other membrane receptors	Inhibits bone resorption by direct inhibition of osteoclast differentiation and activity
Net effect on calcium and phosphate concentrations in extracellular fluid and serum	**Increased serum calcium** **Decreased serum phosphate**	**Increased serum calcium**	**Decreased serum calcium (transient)**

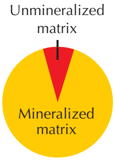
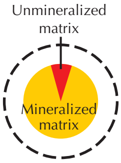
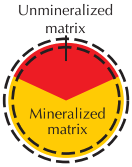
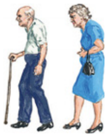
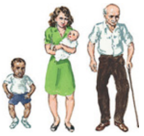
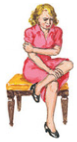
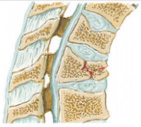
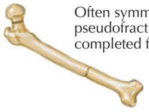
HORMONE	COMMENT
BONE REGULATION	
Parathyroid hormone (PTH)	• Low serum calcium triggers PTH release. PTH binds 1. osteoblasts (which stimulate osteoclasts to resorb bone), 2. osteocytes (to release Ca^{++}), 3. kidney (increase Ca^{++} reabsorption)
Vitamin D 1,25 (OH)	• Vitamin D from skin (UV light) or diet is hydroxylated twice ([1-liver], [25-kidney]) • Vit. D 1,25 triggered by low serum Ca^{++} stimulates uptake in intestine and bone resorption
Calcitonin	• Released when serum Ca^{++} is elevated. Directly inhibits osteoclasts (bone resorption) and increases urinary excretion from kidneys, thus lowering serum levels
Other hormones	• Estrogen, corticosteroids, thyroid hormone, insulin, growth hormone

Dynamics of Bone Homeostasis

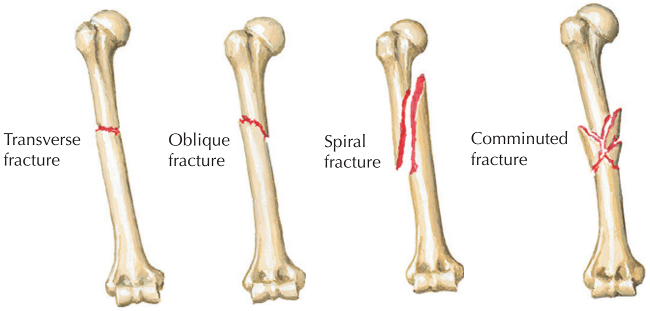

Cortical (compact)
Trabecular
Cortical (compact)
Active osteocytes maintain bone
Lining cells (inactive osteocytes)
Osteoid (hypo-mineralized matrix)
Osteoblasts form osteoid (bone matrix)
Periosteum
Endosteum
Osteoclasts resorb bone
Weight-bearing activity and use of antigravity muscles
Ovaries
Estrogen
Testes
Testosterone
Pituitary
Growth hormone (normal level)
Thyroid
Thyroid hormone (normal level)
Promote net bone formation (osteoblastic bone formation > osteoclastic bone resorption)
500 mg/day of Ca++
Vitamin C and other cofactors needed for osteoid (matrix) formation
500 mg/day of Ca++
Promote net bone resorption (osteoclastic bone resorption > osteoblastic bone formation)
Lack of weight-bearing activity or decreased use of antigravity muscles
Adrenal cortex
Glucocorticoids (decrease Ca++ absorption from intestine)
Excess hormone
Thyroid
PTH
Stimulated by low serum Ca++ and acidosis
Para-thyroids
Acidosis
Intake Ca 800 mg/day
Ca
Amino acids
Ca
Adequate intake and absorption of Ca++ needed to maintain blood and tissue-fluid levels. Levels regulated by PTH, 1,25(OH)2D, and calcitonin
8,000 mg/day filtered
Ca
Ca
Ca 500 mg/day absorbed
Protein (urea)
1,25(OH)2D promotes Ca++ absorption
Intestine
Ca
Ca 300 mg/day returned to intestine
7,800 mg/day reabsorbed
Ca
Renal tubule
Amino acids (adequate intake and absorption of protein needed for bone matrix formation)
Blood and tissue fluid
F. Netter M.D.
600 mg/day lost in stool
Ca
Ca
800 mg/day (loss = intake)
*All Ca are Ca++
200 mg/day lost in urine
Ca

CONDITION	COMMENT
METABOLIC DISORDERS	
Hypercalcemia	• Symptoms: constipation, nausea, abdominal pain, confusion, stupor, coma
1° Hyperparathyroidism	• Typically from parathyroid adenoma and/or overproduction of PTH hormone • "Brown tumors" form. Labs: increased serum calcium, decreased serum phosphate
2° Hyperparathyroidism	• Malignancy (lung CA produces PTH-like protein), MEN syndromes
Hypocalcemia	• Symptoms: hyperreflexia, tetany, +Chvostek's/Trousseau sign(s), papilledema
Hypoparathyroidism	• Due to decreased PTH production, results in decreased serum calcium levels • Can occur after thyroidectomy with inadvertent excision of parathyroid glands
Renal osteodystrophy	• Due to one of many diseases resulting in chronic renal failure
Rickets/osteomalacia	• Failure to properly mineralize the bone matrix (qualitative problem) • Due to Vitamin D deficiency (nutritional) or receptor defect (usually hereditary)

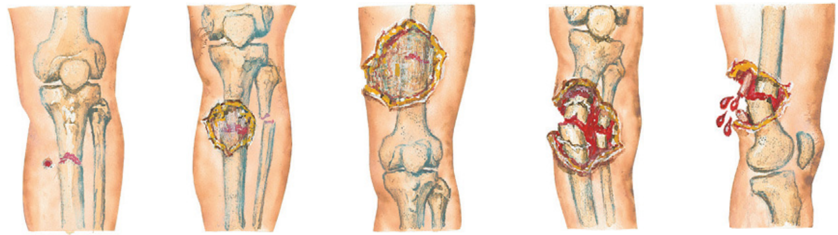
Comparison of Osteoporosis and Osteomalacia

	Osteoporosis	Osteomalacia
Definition  Normal	 Bone mass decreased, mineralization normal	 Bone mass variable, mineralization decreased
Age at onset	 Generally elderly, postmenopause	 Any age
Etiology	Endocrine abnormality, age, idiopathic, inactivity, disuse, alcoholism, calcium deficiency	Vitamin D deficiency, abnormality of vitamin D pathway, hypophosphatemic syndromes, renal tubular acidosis, hypophosphatasia
Symptomatology	 Pain referable to fracture site	 Generalized bone pain
Signs	Tenderness at fracture site	Tenderness at fracture site and generalized tenderness
Radiographic features	 Axial predominance	 Often symmetric, pseudofractures, or completed fractures Appendicular predominance
Laboratory findings Serum Ca^{++}	Normal	Low or normal (high in hypophosphatasia)
Serum P_i	Normal $Ca^{++} \times P_i > 30$	Low or normal $Ca^{++} \times P_i > 30$ if albumin normal (high in renal osteodystrophy)
Alkaline phosphatase	Normal	Elevated, except in hypophosphatasia
Urinary Ca^{++}	High or normal	Normal or low (high in hypophosphatasia)
Bone biopsy	Tetracycline labels normal	Tetracycline labels abnormal

CONDITION	COMMENT
	METABOLIC DISORDERS
Osteoporosis	• Decrease in bone mass (quantitative problem). Most common in elderly patients • 2 types: Type 1: most common, affects cancellous bone (femoral neck, vertebral body, etc); Type 2: age related, >70y.o. Both cancellous and cortical bone mass are deficient. • DEXA scan is standard for evaluation. Hormone replacement or bisphosphonates may be used.
Scurvy	• Vitamin C deficiency leads to defective collagen, resulting in a constellation of symptoms.
Osteopetrosis	• "Marble bone disease". Osteoclast dysfunction results in too much bone density.
Paget's disease	• Simultaneous osteoblast & osteoclast activity results in dense, but brittle bones.



Gustilo and Anderson classification of open fracture



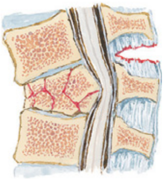
Type I. Wound <1 cm long. No evidence of deep contamination

Type II. Wound >1 cm long. No extensive soft tissue damage

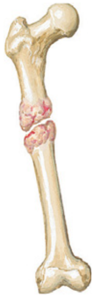
Type IIIA. Large wound. Good soft tissue coverage

Type IIIB. Large wound. Exposed bone fragments, extensive stripping of periosteum. Needs coverage

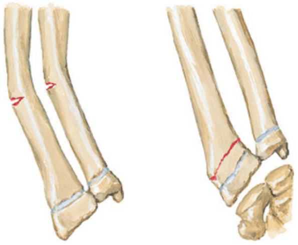
Type IIIC. Large wound with major arterial injury



Compression fracture



Pathologic fracture (tumor or bone disease)



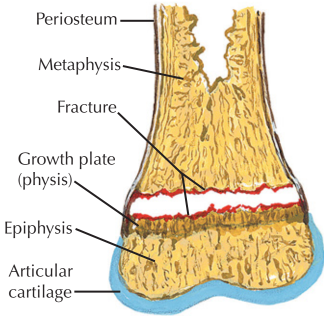
Greenstick fracture

Torus (buckle) fracture

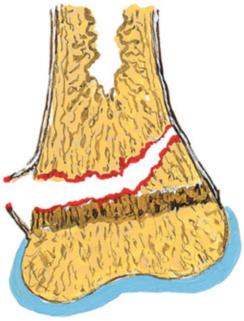
In children

DESCRIPTION	COMMENT
FRACTURES	
Type/description	• Transverse, oblique, spiral, comminuted, segmental, impacted, avulsion
Displacement	• Nondisplaced, minimally displaced, displaced
Angulation	• Direction of distal fragment (e.g., dorsal displacement) or direction of apex (e.g., apex volar)
Open vs closed	• Open if bone penetrated skin resulting in open wound (surgical emergency for infection risk) • Gustilo & Anderson classification of open fractures (I, II, III a,b,c) is commonly used
Other	• Compression: failure of bone due to compressive load. • Salter-Harris: pediatric fracture involving an open physis (growth plate) • Greenstick: pediatric fracture with disruption of a single cortex • Buckle/torus: pediatric fracture involving an impacted cortex • Pathologic: fracture resulting from a diseased bone/bone tumor

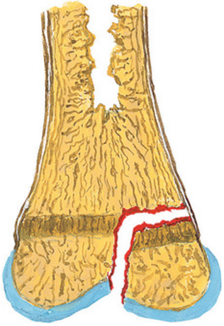
Injury to Growth Plate (Salter-Harris Classification, Rang Modification)



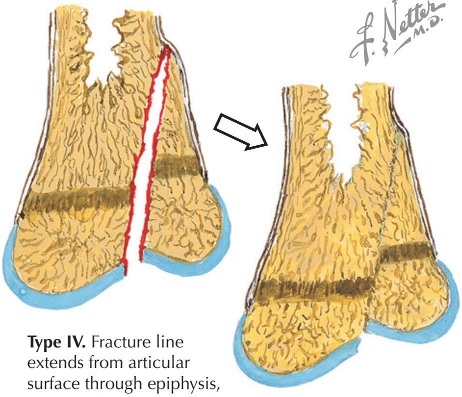
Type I. Complete separation of epiphysis from shaft through calcified cartilage (growth zone) of growth plate. No bone actually fractured; periosteum may remain intact. Most common in newborns and young children



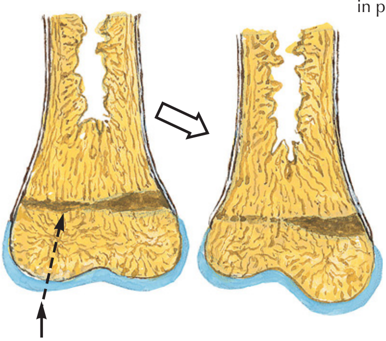
Type II. Most common. Line of separation extends partially across deep layer of growth plate and extends through metaphysis, leaving triangular portion of metaphysis attached to epiphyseal fragment



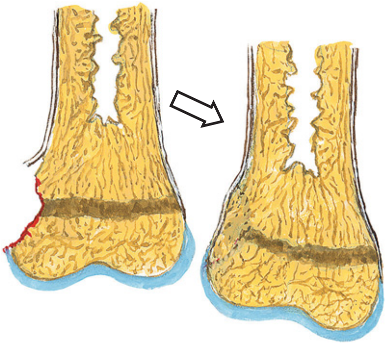
Type III. Uncommon. Intra-articular fracture through epiphysis, across deep zone of growth plate to periphery. Open reduction and fixation often necessary



Type IV. Fracture line extends from articular surface through epiphysis, growth plate, and metaphysis. If fractured segment not perfectly realigned with open reduction, osseous bridge across growth plate may occur, resulting in partial growth arrest and joint angulation

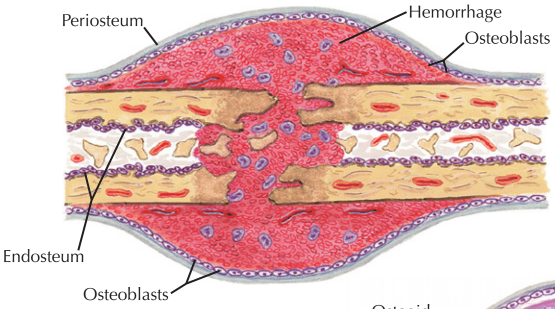


Type V. Severe crushing force transmitted across epiphysis to portion of growth plate by abduction or adduction stress or axial load. Minimal or no displacement makes radiographic diagnosis difficult; growth plate may nevertheless be damaged, resulting in partial growth arrest or shortening and angular deformity

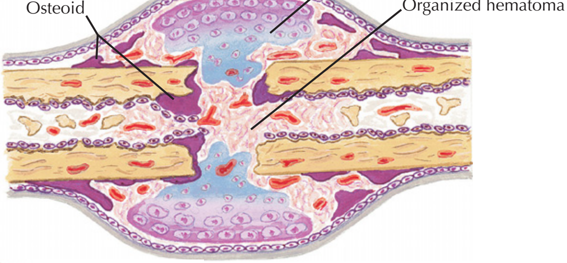


Type VI. Portion of growth plate sheared or cut off. Raw surface heals by forming bone bridge across growth plate, limiting growth on injured side and resulting in angular deformity

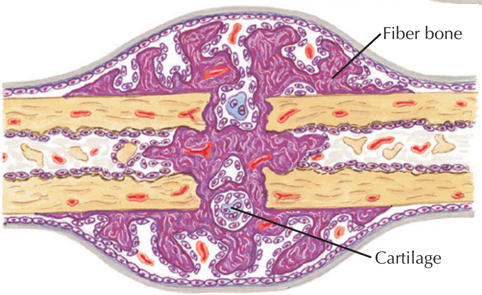
Healing of fracture



Inflammation
A hematoma forms as the result of disruption of intraosseous and surrounding vessels. Bone at the edges of the fracture dies. Bone necrosis is greater with larger amounts of soft tissue disruption. Inflammatory cells are followed by fibroblasts, chondroblasts, and osteoprogenitor cells. Low pO_2 at the fracture site promotes angiogenesis.

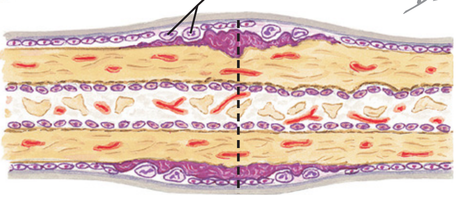


Repair of soft callus formation
Soft callus forms, initially composed of collagen; this is followed by progressive cartilage and osteoid formation.



Repair of hard callus formation
Osteoid and cartilage of external, periosteal, and medullary soft callus become mineralized as they are converted to woven bone (hard callus)

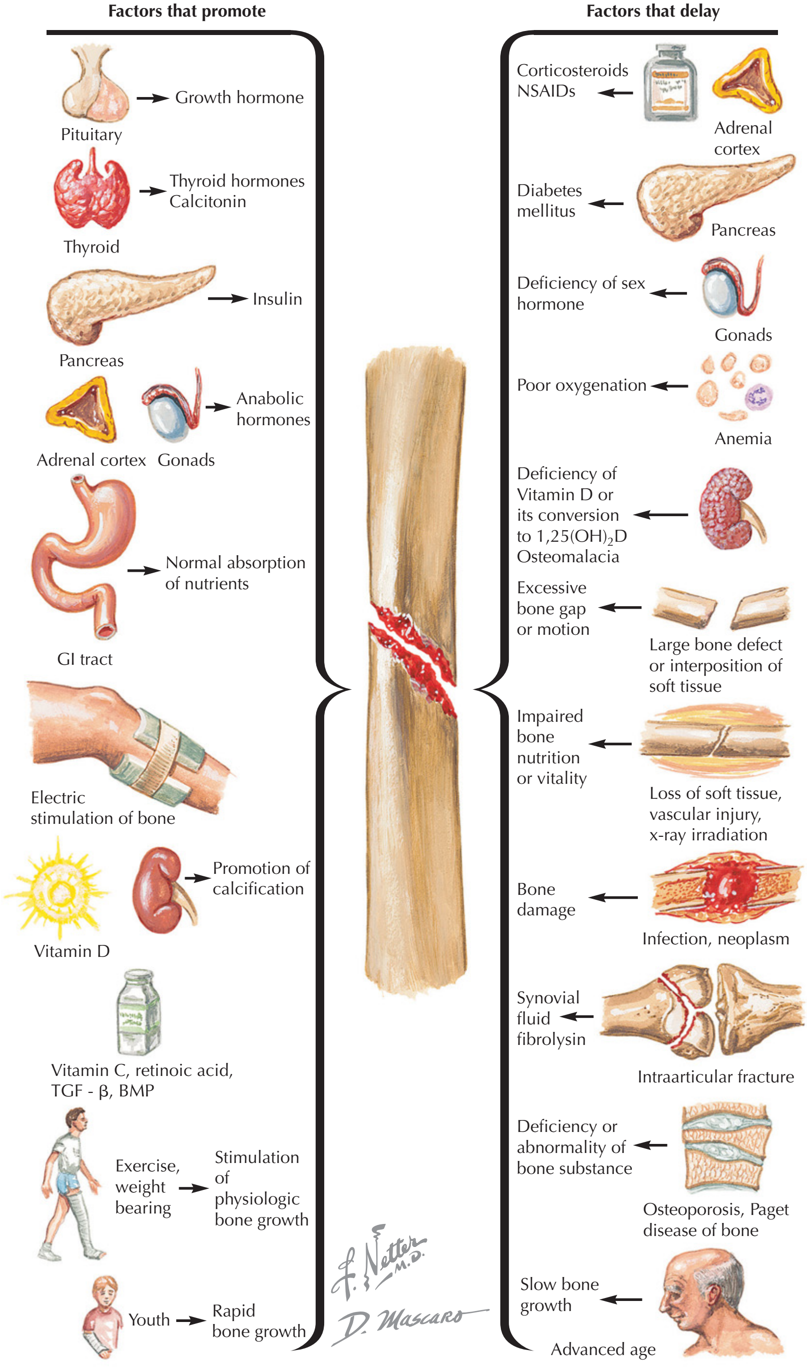
F. Netter M.D.
D. Mascaro



Remodeling
Osteoclastic and osteoblastic activity converts woven bone to lamellar bone with true haversian systems. Normal bone contours are restored; even angulation may be partially or completely corrected.

STAGE	COMMENT
FRACTURE HEALING	
Fracture healing occurs as a continuum with three stages: inflammation, repair (callus formation), remodeling. • To heal, most fractures require good blood supply (most important) and stability. • Callus formation does not occur after rigid fixation of fractures (ORIF); instead primary/direct healing occurs. • Smoking and NSAIDs both inhibit bone/fracture healing.	
Inflammation	• Hematoma develops & supplies hematopoietic/osteoprogenitor cells. Granulation tissue forms.
Repair	• Soft callus: cells produce a cartilage (soft) callus that bridges the bone ends (bridging callus) • Hard callus: replacement of soft callus into immature (woven) bone (enchondral ossification)
Remodeling	• Immature (woven) bone is replaced by mature (lamellar) bone

Factors That Promote or Delay Bone Healing


Factors that promote
Pituitary
Growth hormone
Thyroid
Thyroid hormones
Calcitonin
Pancreas
Insulin
Adrenal cortex
Gonads
Anabolic hormones
GI tract
Normal absorption of nutrients
Electric stimulation of bone
Vitamin D
Promotion of calcification
Vitamin C, retinoic acid, TGF - β, BMP
Exercise, weight bearing
Stimulation of physiologic bone growth
Youth
Rapid bone growth
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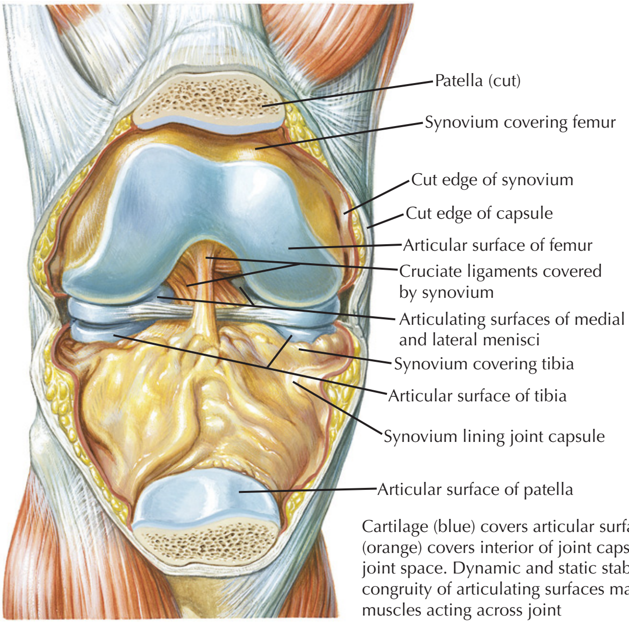
Factors that delay
Corticosteroids
NSAIDs
Adrenal cortex
Diabetes mellitus
Pancreas
Deficiency of sex hormone
Gonads
Poor oxygenation
Anemia
Deficiency of Vitamin D or its conversion to $1,25(OH)_2D$
Osteomalacia
Excessive bone gap or motion
Large bone defect or interposition of soft tissue
Impaired bone nutrition or vitality
Loss of soft tissue, vascular injury, x-ray irradiation
Bone damage
Infection, neoplasm
Synovial fluid fibrolysin
Intraarticular fracture
Deficiency or abnormality of bone substance
Osteoporosis, Paget disease of bone
Slow bone growth
Advanced age

Synovial joints

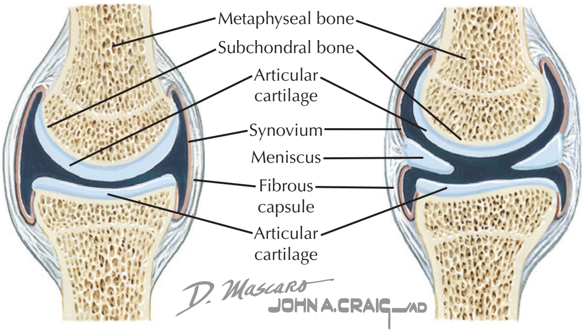

Patella (cut)
Synovium covering femur
Cut edge of synovium
Cut edge of capsule
Articular surface of femur
Cruciate ligaments covered by synovium
Articulating surfaces of medial and lateral menisci
Synovium covering tibia
Articular surface of tibia
Synovium lining joint capsule
Articular surface of patella

Anterior view of open knee

Cartilage (blue) covers articular surfaces; synovial membrane (orange) covers interior of joint capsule and ligaments, traversing joint space. Dynamic and static stability of joint and relative congruity of articulating surfaces maintained by ligaments and muscles acting across joint

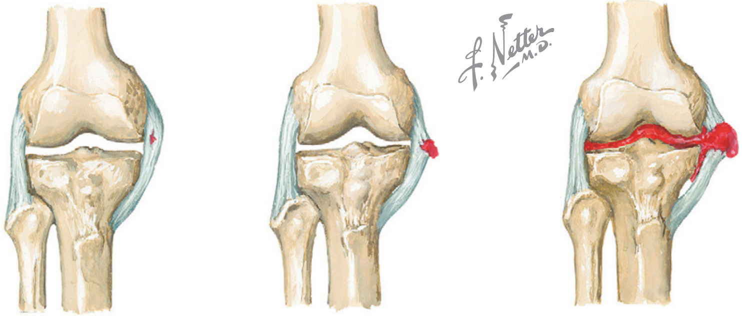
STRUCTURE	COMMENT
	JOINTS
Synovial (diarthrodial) joints are found at the ends of two adjacent bones that articulate.	
Articular cartilage	• Extremely smooth (nearly frictionless) covering of the bone ends that glide on each other • It can be injured leading to pain, degeneration, or dysfunction
Subchondral bone	• Dense bone that supports and is found directly beneath the articular cartilage • Appears radiodense on plain film x-rays and has low signal (black) on MR
Synovium	• Inner membrane lines the joint capsule • “Makes” (filters plasma to produce) synovial fluid • Synovial folds (plica) form normally but occasionally can be pathologic
Capsule	• Outer layer, surrounds and supports the ends of two bones in proper orientation • Thickenings of the capsule (capsular ligaments) maintain stability of the joint
Synovial fluid	• Ultrafiltrate of plasma (synovium filters it) • Composed of hyaluronic acid, lubricin, proteinase, and collagenases. Viscosupplementation therapy aims to replace hyaluronic acid in the joint • Function: 1. Lubrication of joint. 2. Nutrition to articular cartilage (and menisci/TFCC, etc) • Laboratory evaluation is important part of workup of intraarticular processes
Other	• Joints often have additional structures within them, including ligaments (e.g., ACL, PCL), tendons (e.g., biceps, popliteus), supporting structures (e.g., meniscus, TFCC, articular discs)
	CARTILAGE
Hyaline	• Found in articular cartilage of synovial joints and cartilage in physes • Contains type II collagen
Fibrocartilage	• Found in meniscus, TFCC, vertebral disc, articular disc (e.g., acromioclavicular joint) • Contains type I collagen

Structure of synovial joints



Typical synovial joints exhibit congruent articular cartilage surfaces supported by subchondral and metaphyseal bone and stabilized by joint capsule and ligaments. Inner surfaces, except for articular cartilage, covered by synovial membrane (synovium)

Degrees of sprain

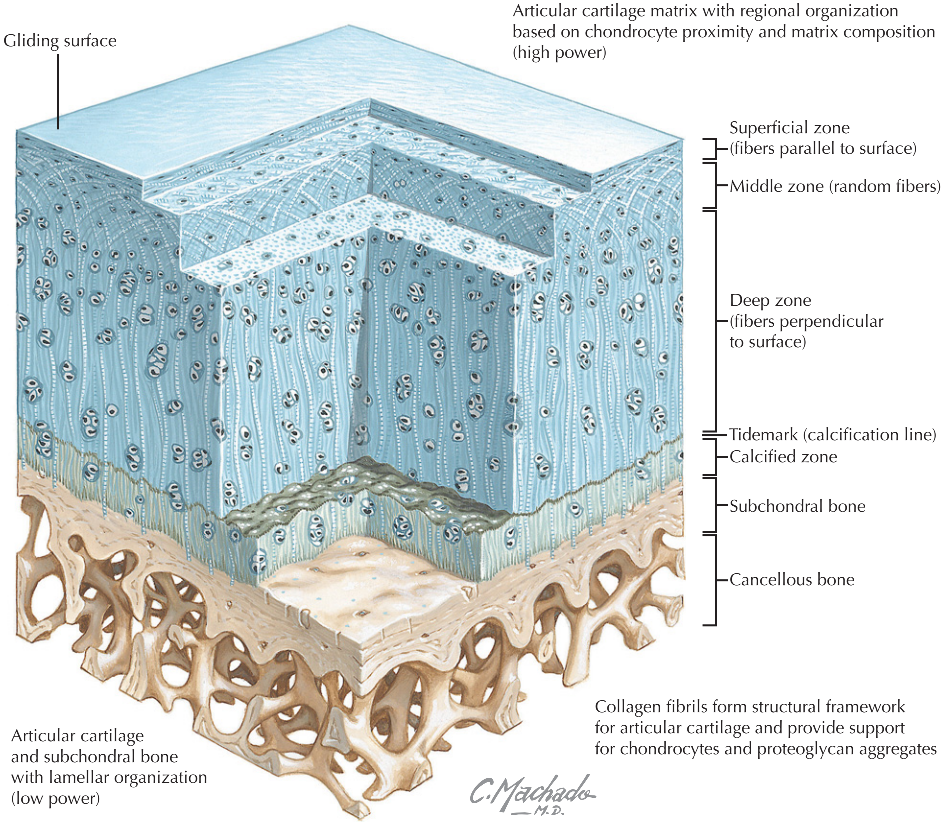


Grade I. Stretching of ligament with minimal disruption of fibers

Grade II. Tearing of up to 50% of ligament fibers; small hematoma. Hemarthrosis may be present

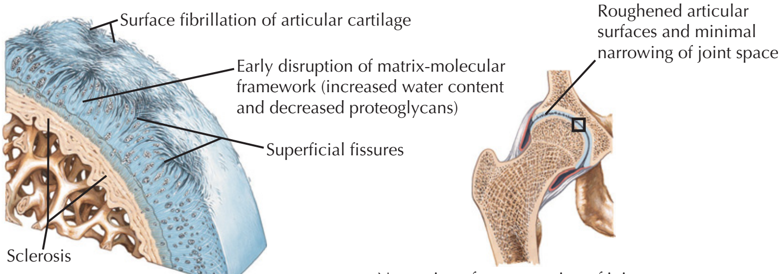
Grade III. Complete tear of ligament and separation of ends, hematoma, and hemarthrosis

STRUCTURE	COMMENT
LIGAMENTS	
Function	• Attach two bones to each other (usually at a joint [ACL] or b/w 2 prominences [suprascapular]) • Ligaments provide stability to a joint allowing for physiologic range of motion
Types	• Ligaments can be discrete structures (e.g., ACL or PCL) • Many ligaments are thickenings of the fibrous joint capsule (e.g., ATFL in ankle)
Insertion	• 1. Ligamentous tissue (primarily type 1 collagen) attaches to fibrocartilage • 2. Fibrocartilage attaches to calcified fibrocartilage (most injuries occur here) • 3. Calcified fibrocartilage (Sharpey's fibers) attaches to bone/periosteum
Injury	• Ligament injuries are termed "sprains" and are graded 1-3 ◦ Grade 1: stretching of ligament. ◦ Grade 2: partial tear of ligament ◦ Grade 3: complete tear of ligament • Adults tend to have midsubstance injuries; children have more avulsion injuries
Treatment	• Depending on ligament: 1. immobilization, 2. therapy, 3. surgical repair, 4. surgical reconstruction
Ligament strength	• Pediatrics: ligament is stronger than physis, so physis usually injured. Sprains are less common. • Adults: ligament is weakest portion of joint, so sprains are common. • Geriatrics: ligament is stronger than weaker bone, so fracture more common than sprain.


Gliding surface
Articular cartilage matrix with regional organization based on chondrocyte proximity and matrix composition (high power)
Superficial zone (fibers parallel to surface)
Middle zone (random fibers)
Deep zone (fibers perpendicular to surface)
Tidemark (calcification line)
Calcified zone
Subchondral bone
Cancellous bone
Collagen fibrils form structural framework for articular cartilage and provide support for chondrocytes and proteoglycan aggregates
Articular cartilage and subchondral bone with lamellar organization (low power)
C. Machado M.D.

STRUCTURE	COMMENT
ARTICULAR CARTILAGE	
Hyaline cartilage covering of intraarticular ends of bones.	
Function	• Smooth (nearly frictionless) surface covering the ends of articulating bones • Allows for pain-free range of motion • Avascular (nutrition from synovial fluid), aneural, alymphatic
Composition	• Water: up to 80% of weight. Changes with load/compression; decr. with age, increases with OA • Collagen: 90+% is type II (also types V, VI, IX, X, XI); gives tensile strength • Proteoglycans: gives compressive strength; decreases with age and allows softening • Chondrocytes: maintains cartilage, produces collagen and proteoglycans
Zones (layers)	• Superficial: thin layer, fibers have tangential orientation (parallel to surface), resists shear • Middle: moderate-sized layer, fibers are randomly/obliquely oriented • Deep: thick layer, fibers are vertical (perpendicular to surface), resists compression • Tidemark: ultrathin line separating deep zone from calcified zone • Calcified zone: transitional zone that attaches cartilage to subchondral bone
Injury & healing	• Articular cartilage is avascular; limited healing capacity, making treatment of injuries problematic • Injuries extending deep to the tidemark may heal with fibrocartilage (not hyaline) • Microfracture surgery is based on stimulating the differentiation of mesenchymal cells within the bone into chondrocytes to produce fibrocartilage healing of articular cartilage injuries

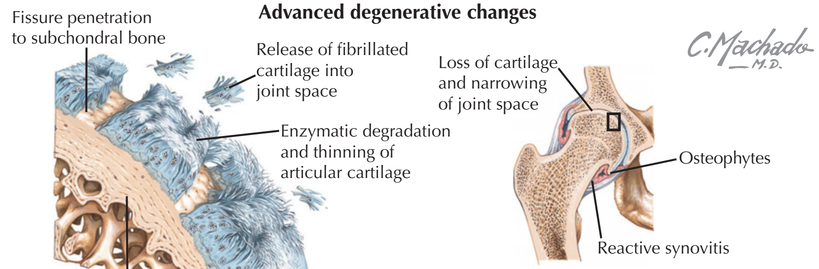
Early degenerative changes


Surface fibrillation of articular cartilage
Early disruption of matrix-molecular framework (increased water content and decreased proteoglycans)
Superficial fissures
Sclerosis
Roughened articular surfaces and minimal narrowing of joint space

Sclerosis (thickening) of subchondral bone early sign of degeneration

Narrowing of upper portion of joint space with early degeneration of articular cartilage

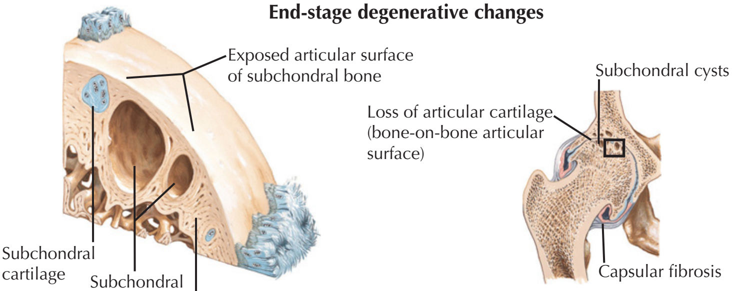
Advanced degenerative changes


Fissure penetration to subchondral bone
Release of fibrillated cartilage into joint space
Enzymatic degradation and thinning of articular cartilage
Loss of cartilage and narrowing of joint space
C. Machado M.D.
Osteophytes
Reactive synovitis

Pronounced sclerosis of subchondral bone

Marked narrowing of joint space with local loss of articular cartilage, osteophyte formation, and bone remodeling

End-stage degenerative changes


Exposed articular surface of subchondral bone
Subchondral cysts
Loss of articular cartilage (bone-on-bone articular surface)
Subchondral cartilage
Subchondral cysts
Subchondral sclerosis
Capsular fibrosis

Articular cartilage lost and joint space narrowed. Bone shows remodeling osteophyte and subchondral cysts.

STRUCTURE	COMMENT
OSTEOARTHRITIS	
Pathophysiology	• Diffuse wear, erosion, or degeneration of articular cartilage • Microscopically: increase in water content, disorganized collagen, proteoglycan breakdown
Etiology	• Primary: idiopathic, no other identifiable cause; common in elderly patient population • Secondary: due to other underlying condition (e.g., posttraumatic, joint dysplasia, etc)
Incidence	• Most common type of arthritis • Common in weight-bearing joints (knee #1, hip), also in spine, DIPJ, PIPJ, & thumb CMCJ
Symptoms	• Worsening pain and disability (cartilage loss allows bones to directly articulate on each other)
Radiographs	• 1. Joint space narrowing, 2. osteophytes, 3. subchondral sclerosis, 4. subchondral cysts
Treatment	• Rest, activity modification, NSAIDs, therapy (ROM), steroid injection, arthrodesis or arthroplasty

Synovial fluid analysis

Analysis

A. Normal. Clear to pale yellow, transparent. WBC < 200

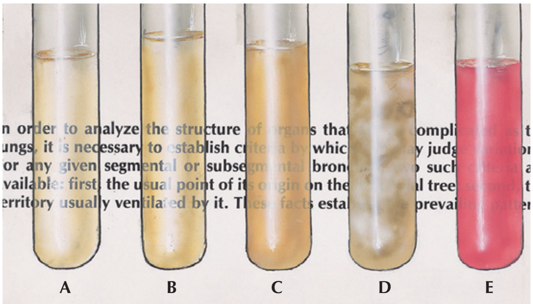
B. Osteoarthritis. Slightly deeper yellow, transparent. WBC <2000

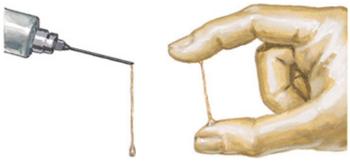
C. Inflammatory. Darker yellow, cloudy, translucent (type blurred or obscured). WBC < 80,000

D. Septic. Purulent, dense, opaque. WBC > 80,000

E. Hemarthrosis. Red, opaque. Must be differentiated from traumatic tap

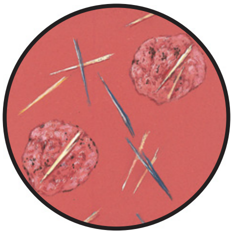
The clarity of the fluid is assessed by expressing a small amount of fluid out of the plastic syringe into a glass tube. Printed words viewed through normal and noninflammatory joint fluid can be read easily.





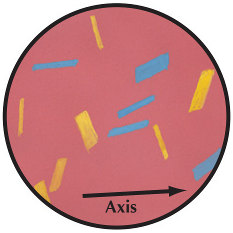
Viscosity. Drop of normal or noninflammatory fluid expressed from needle will string out 1 in or more, indicative of high viscosity. Inflammatory fluid evidences little or no stringing. Viscosity may also be tested between *gloved* thumb and forefinger.

Gout



Free and phagocytized monosodium urate crystals in aspirated joint fluid seen on compensated polarized light microscopy. Negatively birefringent crystals are yellow when parallel to axis.

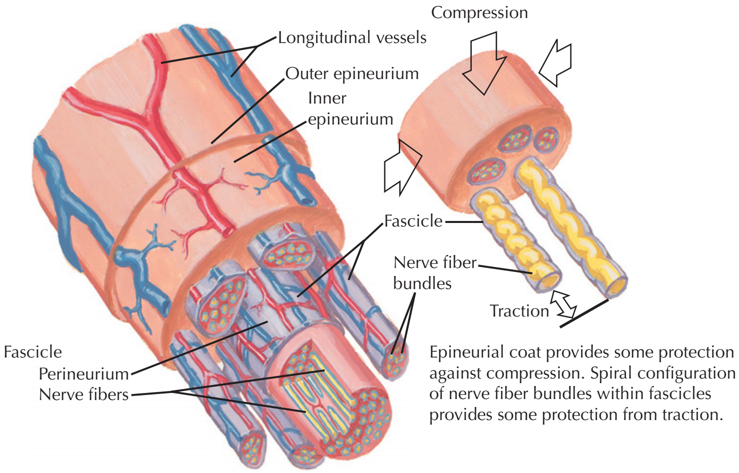
Pseudogout



Diagnosis made on basis of demonstration of weakly positive birefringent, rhomboid-shaped calcium pyrophosphate dihydrate crystals in synovial fluid aspirate of involved joints

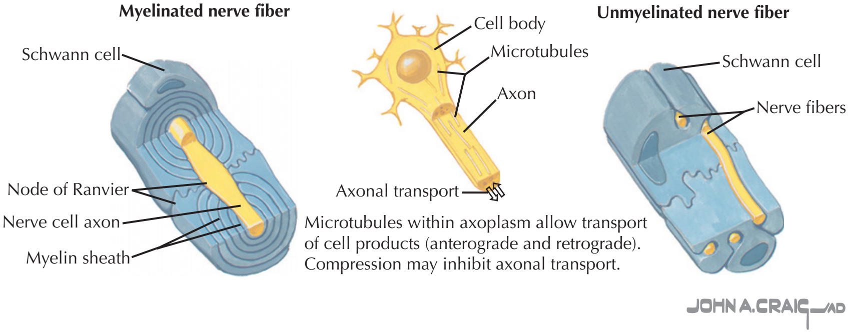
TYPE	COMMENT
INFLAMMATORY ARTHRITIS	
Rheumatoid arthritis	• Autoimmune disorder targeting the joint synovium • Chronic synovitis and pannus formation lead to articular surface degeneration and eventually joint destruction • Women 3:1; Labs: +RF, HLA-DR4; monocytes mediate the disease effect • Multiple extraarticular manifestations: ocular, skin nodules, vasculitis • Characterized by warm, painful joints with progressive deformity (e.g., ulnar deviation of fingers) • Radiographic findings: 1. joint space narrowing, 2. osteopenia, 3. bone/joint erosion • Treatment: primarily medical until advanced stages necessitate surgical reconstruction
Gout	• Monosodium urate crystal deposition in joint/synovium • Labs: elevated serum uric acid; synovial analysis: negatively birefringent crystals • Typical presentation: monoarticular arthritis (1st MTPJ #1 site); symptoms can be self-limiting • Treatment consists of indomethacin (NSAID) & colchicine
Pseudogout	• Deposition of calcium pyrophosphate dihydrate crystals (CPPD) in the joint • Chondrocalcinosis (calcification of cartilage) can also occur (e.g., calcification of meniscus) • Monoarticular arthritis in older patient is typical presentation; women>men • Synovial analysis shows weakly positive birefringent crystals
Reiter's syndrome	• Triad: urethritis, conjunctivitis, arthritis. Labs: +HLA-B27

Anatomy of Peripheral Nerve


Compression
Longitudinal vessels
Outer epineurium
Inner epineurium
Fascicle
Nerve fiber bundles
Traction
Fascicle
Perineurium
Nerve fibers

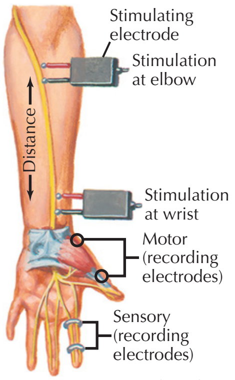
Epineurial coat provides some protection against compression. Spiral configuration of nerve fiber bundles within fascicles provides some protection from traction.

Nerve Fiber Types


Myelinated nerve fiber
Schwann cell
Node of Ranvier
Nerve cell axon
Myelin sheath
Cell body
Microtubules
Axon
Axonal transport
Unmyelinated nerve fiber
Schwann cell
Nerve fibers
JOHN A.CRAIG AD

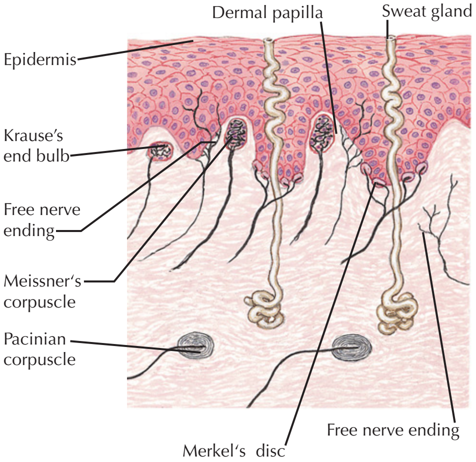
Microtubules within axoplasm allow transport of cell products (anterograde and retrograde). Compression may inhibit axonal transport.

STRUCTURE	**COMMENT**
	NERVE ANATOMY
Neuron	• A nerve cell made up of cell body (in dorsal root ganglion [DRG] for afferent fibers, in ventral horn for efferent fibers), dendrites (receive signal), axon (transmit signal), presynaptic terminal
Glial cells	• Schwann cell produces myelin to cover the axon; myelin increases conduction speed
Node of Ranvier	• Gap between Schwann cells; facilitates conduction of action potentials/impulse signals
Nerve fiber	• A single axon. 3 types: large/myelinated fibers are fast, small/unmyelinated are slow • Efferent fibers (axons) transmit motor signals from CNS via ventral horn to peripheral muscles • Afferent fibers (axons) transmit sensory signals from peripheral receptor via DRG to CNS
Fascicle	• A group of nerve fibers surrounded by perineurium • Fascicles unite and divide (form plexi) continuously along the course of the nerve
Peripheral nerve	• One or more fascicles surrounded by epineurium • Most peripheral nerves have both motor and sensory fascicles
Epineurium	• Surrounds all fascicles of peripheral nerve; protects and nourishes fascicles
Perineurium	• Surrounds individual fascicles; provides tensile strength to peripheral nerve
Endoneurium	• Surrounds nerve fibers (axons); protects and nourishes nerve fibers
Blood supply	• Intrinsic: vascular plexus within the endoneurium, perineurium, and epineurium • Extrinsic: vessels that enter the epineurium along its course

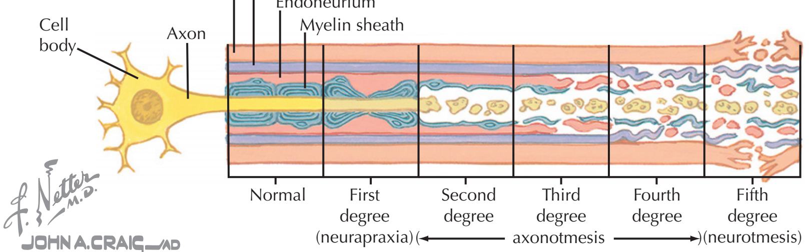


Nerve conduction studies

Stimulating electrode
Stimulation at elbow
Distance
Stimulation at wrist
Motor (recording electrodes)
Sensory (recording electrodes)



Dermal papilla
Sweat gland
Epidermis
Krause's end bulb
Free nerve ending
Meissner's corpuscle
Pacinian corpuscle
Free nerve ending
Merkel's disc



Epineurium
Perineurium
Endoneurium
Myelin sheath
Cell body
Axon
Normal
First degree (neurapraxia)
Second degree
Third degree
Fourth degree
axonotmesis
Fifth degree (neurotmesis)
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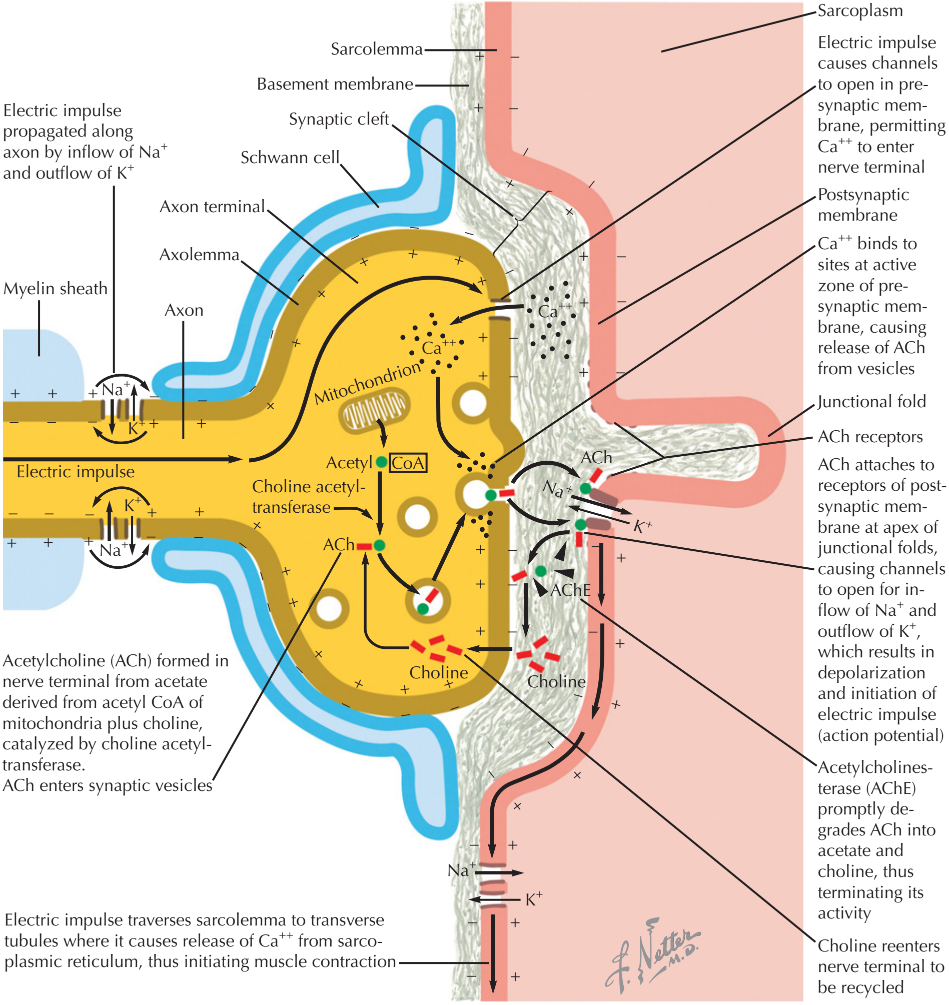
Classification of nerve injury by degree of involvement of various neural layers

STRUCTURE	COMMENT
	NERVE FUNCTION
Nerve conduction	• Resting potential: a polar difference is maintained between intracellular & extracellular environments • Action potential: change in Na^+ permeability depolarizes cells, produces signal conduction
Nerve conduction study (NCS)	• Measures nerve conduction velocity by using a combination of stimulating & recording electrodes • Velocity can be decreased by compression or demyelination (injury or disease)
Receptors	• Multiple types: pain, pressure, thermal, mechanical, etc • Pacinian corpuscle: pressure; Meissner: dynamic 2pt (rapid); Merkel: static 2pt (static)
Disorders	• **Guillain-Barré:** ascending motor weakness/paralysis. Caused by demyelination of peripheral nerves. Typically follows a viral syndrome. Most cases are self-limiting. May need IV IG. • **Charcot-Marie-Tooth:** Autosomal dominant disorder. Demyelinating disorder affecting motor>sensory nerves. Peroneals, hand & foot intrinsics commonly affected: cavus feet, claw toes.
	NERVE INJURY
Classification	• Seddon: 3 categories of injury: neurapraxia, axonotmesis, and neurotmesis • Sunderland: 5 degrees (axonotmesis subdivided into 3 based on intact endo, peri, or epineurium)
Neurapraxia	• Local myelin damage (often from compression), axon is intact; no distal degeneration
Axonotmesis	• Disruption of axon & myelin, epineurium is intact; Wallerian degeneration occurs
Neurotmesis	• Complete disruption of the nerve; poor prognosis; nerve repair typically needed

Physiology of Neuromuscular Junction


Sarcolemma
Basement membrane
Synaptic cleft
Schwann cell
Axon terminal
Axolemma
Myelin sheath
Axon
Na^+
K^+
Electric impulse
Mitochondrion
Ca^{++}
Acetyl CoA
Choline acetyl-transferase
ACh
Choline
AChE
Na^+
K^+
Sarcoplasm
Postsynaptic membrane
Junctional fold
ACh receptors
F. Netter M.D.

Electric impulse propagated along axon by inflow of Na^+ and outflow of K^+

Acetylcholine (ACh) formed in nerve terminal from acetate derived from acetyl CoA of mitochondria plus choline, catalyzed by choline acetyltransferase. ACh enters synaptic vesicles

Electric impulse traverses sarcolemma to transverse tubules where it causes release of Ca^{++} from sarcoplasmic reticulum, thus initiating muscle contraction

Electric impulse causes channels to open in presynaptic membrane, permitting Ca^{++} to enter nerve terminal

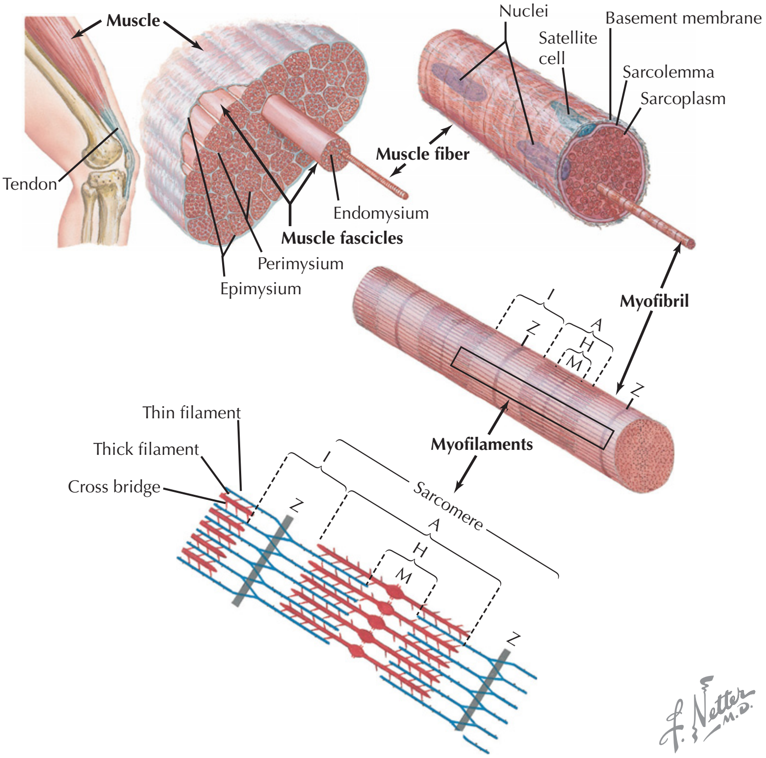
Ca^{++} binds to sites at active zone of presynaptic membrane, causing release of ACh from vesicles

ACh attaches to receptors of postsynaptic membrane at apex of junctional folds, causing channels to open for inflow of Na^+ and outflow of K^+, which results in depolarization and initiation of electric impulse (action potential)

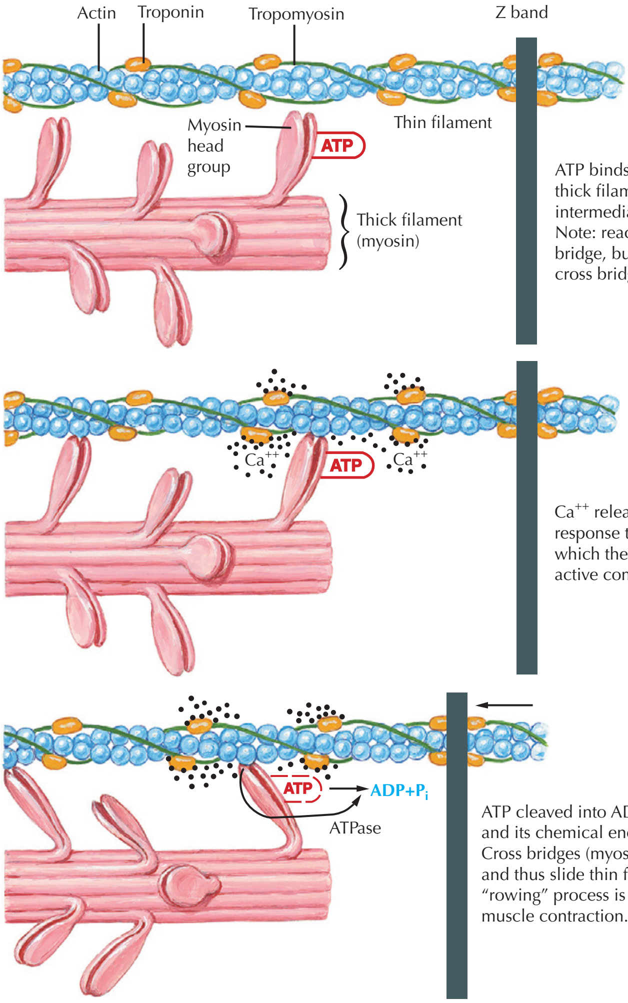
Acetylcholinesterase (AChE) promptly degrades ACh into acetate and choline, thus terminating its activity

Choline reenters nerve terminal to be recycled

STRUCTURE	COMMENT
NEUROMUSCULAR JUNCTION	
Neuromuscular junction	• Axon of motor neuron synapses with the muscle (motor end plate). • Acetylcholine (the neurotransmitter) stored in axon crosses the synaptic cleft and binds to receptors on the sarcoplasmic reticulum and depolarizes it.
Motor unit	• All the muscles fibers innervated by a single motor neuron
Electromyography (EMG)	• Evaluates motor units to determine if muscle dysfunction is from the nerve, neuromuscular junction, or the muscle itself. Fibrillation is abnormal.
Disorders	• **Myasthenia gravis:** relative shortage of acetylcholine receptors due to competitive binding to them by thymus-derived antibodies. Treatment involves thymectomy or anti-acetylcholinesterase agents.


Muscle
Tendon
Epimysium
Perimysium
Muscle fascicles
Endomysium
Muscle fiber
Nuclei
Satellite cell
Basement membrane
Sarcolemma
Sarcoplasm
Myofibril
I
Z
A
H
M
Z
Myofilaments
Thin filament
Thick filament
Cross bridge
Sarcomere
A
H
M
Z
Z

STRUCTURE	COMMENT
	MUSCLE ANATOMY
Types of muscle	• Smooth (e.g., bowel), cardiac, and skeletal • Skeletal muscle: under voluntary control; has an origin and insertion • Types: type 1 “slow twitch” are aerobic; type 2 “fast twitch” are anaerobic
Muscle	• Composed of multiple fascicles (bundles) surrounded by epimysium
Fascicle (bundle)	• Composed of multiple muscle fibers (cells) surrounded by perimysium
Fiber (cell)	• Elongated muscle cell composed of multiple myofibrils surrounded by endomysium
Myofibril	• Composed of multiple myofilaments arranged end to end without a surrounding tissue
Sarcomere	• Composed of interdigitated thick (myosin) and thin (actin) filaments organized into bands • Z line to Z line defines the length of the sarcomere • A band: length of the thick filament, does not change with contraction • I band (actin only), H band (myosin only), and sarcomere length all change with contraction
Myosin	• Thick filament; has “head” that binds ATP and attaches to thin filaments (actin)
Actin	• Thin filament; fixed to Z bands, associated with troponin and tropomyosin
Troponin	• Associated with actin and tropomyosin, binds Ca^{++} ions
Tropomyosin	• Long molecule lies in helical groove of actin and blocks myosin from binding to the actin
Sarcoplasmic reticulum	• Stores intracellular calcium ions (in T tubules), which are stimulated to be released during contraction



Biochemical Mechanics of Muscle Contraction

ATP binds to myosin head groups protruding from thick filaments, forming charged myosin-ATP intermediates, not yet attached to thin filaments. Note: reactions shown occurring at only one cross bridge, but same process takes place at all or most cross bridges.

Ca^{++} released from sarcoplasmic reticulum in response to electric impluse binds to troponin, which then permits charged intermediates to form active complexes with actin of thin filaments.

ATP cleaved into ADP and Pi by ATPase of active complexes, and its chemical energy thus converted to mechanical energy. Cross bridges (myosin head groups) flex into rigor position and thus slide thin filaments along thick filaments. This "rowing" process is repeated over and over, producing muscle contraction.

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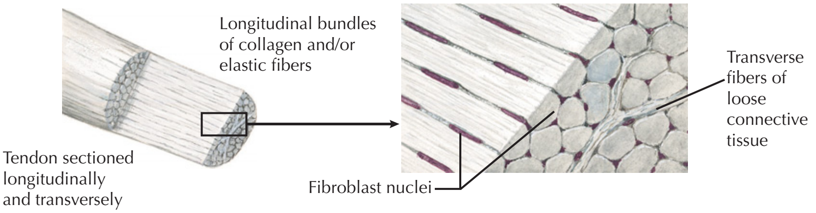
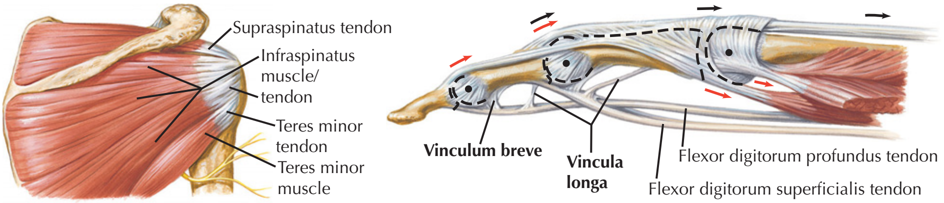
COMMENT	
MUSCLE CONTRACTION	
Steps	• Contraction initiated when acetylcholine binds to receptors on the sarcoplasmic reticulum, depolarizing it • Depolarization causes release of Ca^{++}, which binds to troponin molecules. This binding causes the tropomyosin to move, allowing the "charged" myosin head (ATP bound) to bind to actin. • Breakdown of the ATP causes contraction of the filament (shortening of the sarcomere) and the release of the filaments (actin and myosin) in preparation to repeat the process.
Types	
Isotonic	• Muscle tension/resistance is the same throughout the contraction
Eccentric	• Muscle elongates as it contracts. Common injury mechanism (e.g., biceps, quadriceps rupture)
Concentric	• Muscle shortens as it contracts
Isometric	• Muscle length is constant (resistance changes)
Isokinetic	• Muscle contracts at constant velocity; best for muscle strengthening

Tendon anatomy

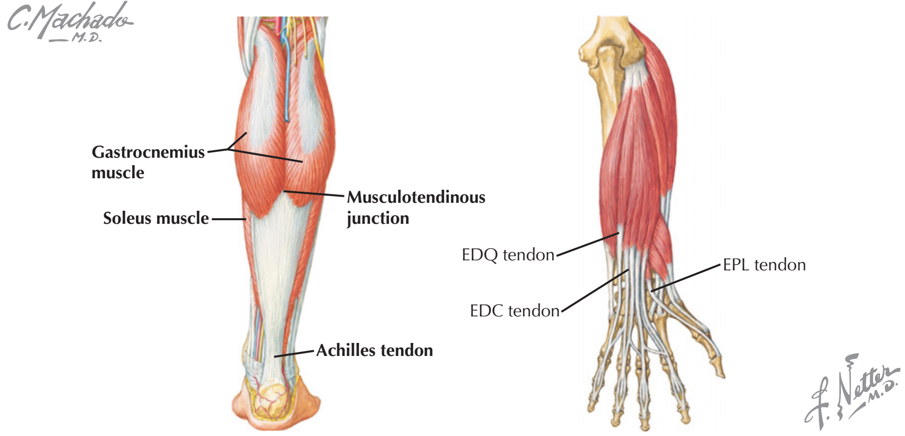

Longitudinal bundles
of collagen and/or
elastic fibers
Transverse
fibers of
loose
connective
tissue
Tendon sectioned
longitudinally
and transversely
Fibroblast nuclei

Types of tendons

Rotator cuff tendon **Avascular tendon**

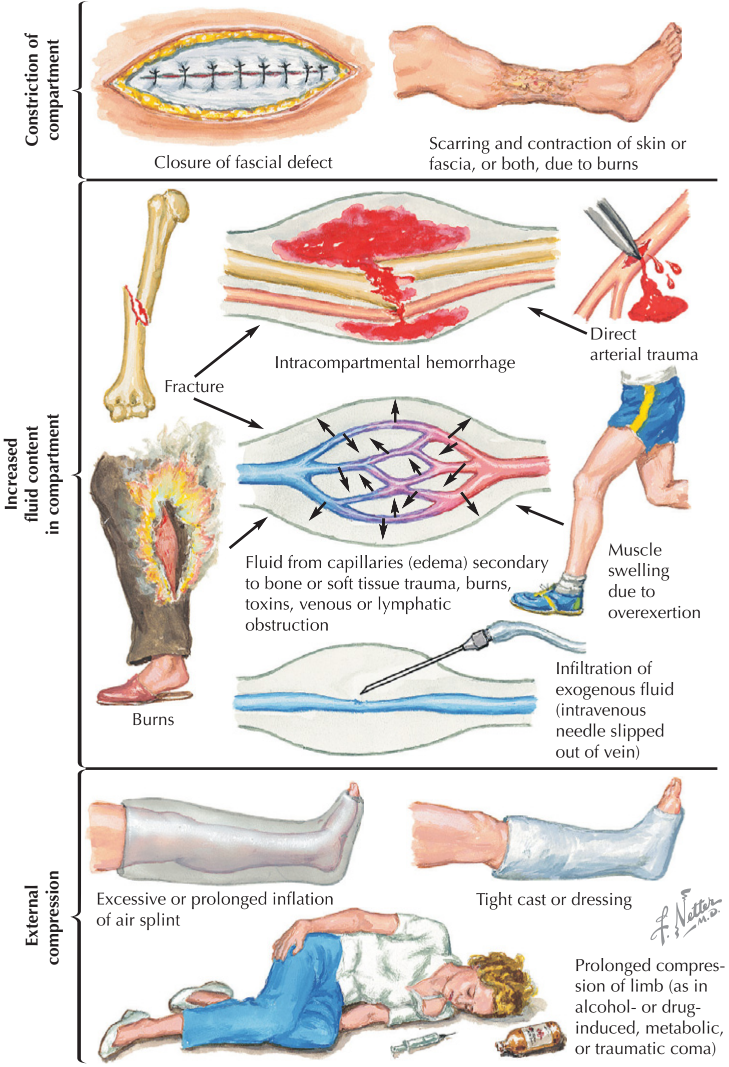

Supraspinatus tendon
Infraspinatus
muscle/
tendon
Teres minor
tendon
Teres minor
muscle
Vinculum breve
Vincula
longa
Flexor digitorum profundus tendon
Flexor digitorum superficialis tendon

Achilles tendon **Extensor tendons**


C. Machado M.D.
Gastrocnemius
muscle
Soleus muscle
Musculotendinous
junction
Achilles tendon
EDQ tendon
EDC tendon
EPL tendon
F. Netter M.D.

STRUCTURE	COMMENT
TENDON	
Function	• Connects muscles to bones so the muscle can exert its effect
Anatomy	• Various shapes and sizes (long, broad, short, flat, etc)
Fibril	• Type 1 collagen grouped into microfibrils, then subfibrils, then fibrils, surrounded by endotenon
Fascicle	• Fibroblasts and fibrils surrounded by a peritenon
Tendon	• Groups of fascicles surrounded by an epitenon
Insertion	• Tendinous tissue (primarily type 1 collagen) attaches to fibrocartilage • Fibrocartilage attaches to calcified fibrocartilage (Sharpey's fibers) • Calcified fibrocartilage (Sharpey's fibers) attaches to bone/periosteum
Blood supply	• Vascular tendons have a paratenon (no sheath) that surrounds them and supplies blood • Avascular tendons (in a sheath) have a vinculum to supply blood
Musculotendinous junction	• Transition from muscle to tendon; weakest portion of the myotendinous complex and site of most injuries

Etiology of Compartment Syndrome


Constriction of compartment
Closure of fascial defect
Scarring and contraction of skin or fascia, or both, due to burns
Increased fluid content in compartment
Intracompartmental hemorrhage
Direct arterial trauma
Fracture
Fluid from capillaries (edema) secondary to bone or soft tissue trauma, burns, toxins, venous or lymphatic obstruction
Muscle swelling due to overexertion
Burns
Infiltration of exogenous fluid (intravenous needle slipped out of vein)
External compression
Excessive or prolonged inflation of air splint
Tight cast or dressing
Prolonged compression of limb (as in alcohol- or drug-induced, metabolic, or traumatic coma)

COMMENT	
MUSCLE COMPARTMENTS	
Muscles are contained within fibro(fascia)-osseous(bone) spaces known as compartments.	
Compartment syndrome	• Results from increased pressure within fibroosseous compartment • Multiple etiologies (fracture/hematoma, edema, burns, compression, etc) • The increased pressure occludes the vascular supply to the compartment muscles • Symptoms: the "5 P's": pain (on passive stretch, most sensitive), paresthesias, pallor, paralysis, pulselessness (a late finding) • Physical exam: firm/tense compartments +/− some or all of the 5 P's; it is a clinical diagnosis • Two methods for intracompartmental pressure tests: 1.absolute value, 2. ΔP from diastolic BP • Compartment release/fasciotomy is a surgical emergency to prevent muscle necrosis/contracture

CHAPTER 2

Spine

Topographic Anatomy 30

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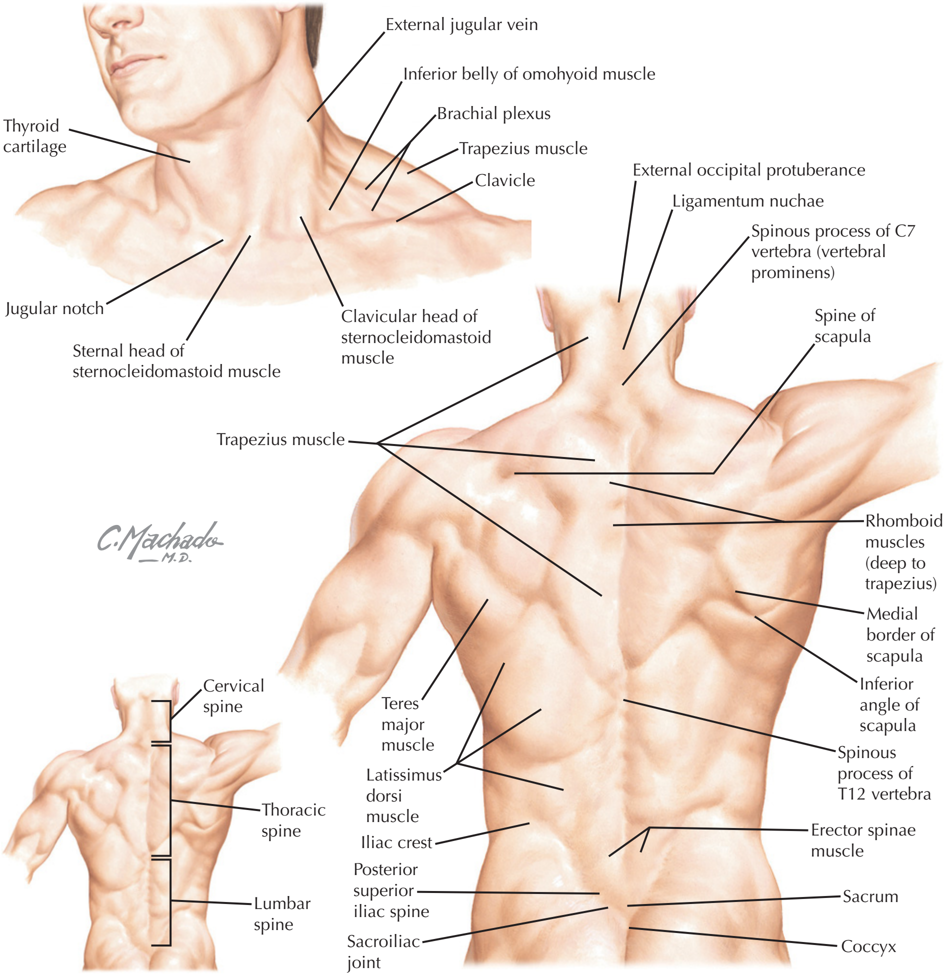

External jugular vein
Inferior belly of omohyoid muscle
Brachial plexus
Trapezius muscle
Clavicle
Thyroid cartilage
Jugular notch
Sternal head of sternocleidomastoid muscle
Clavicular head of sternocleidomastoid muscle
External occipital protuberance
Ligamentum nuchae
Spinous process of C7 vertebra (vertebral prominens)
Spine of scapula
Trapezius muscle
Rhomboid muscles (deep to trapezius)
Medial border of scapula
Inferior angle of scapula
Spinous process of T12 vertebra
Teres major muscle
Latissimus dorsi muscle
Iliac crest
Erector spinae muscle
Posterior superior iliac spine
Sacrum
Sacroiliac joint
Coccyx
Cervical spine
Thoracic spine
Lumbar spine

STRUCTURE	CLINICAL APPLICATION
Brachial plexus	Interscalene nerve block commonly used for upper extremity procedures
Sternocleidomastoid	Contracted in torticollis
Trapezius	Large muscle, muscle spasm common cause of neck and upper back pain
Rhomboid muscles	Overuse and spasm common cause of upper back pain
C7 spinous process	"Vertebral prominens" is an easily palpable landmark
Iliac crest	Site for "hip pointers" (contusion of lilac crest) Common site for autologous bone graft harvest
Erector spinae muscles	Overuse and spasm are common causes of lower back pain (LBP)
Posterior superior iliac spine	Site of bone graft harvest in posterior spinal procedures
Sacroiliac joint	Degeneration or injury to joint can cause lower back pain
Coccyx	Distal end of vertebral column (tailbone), can be fractured in a fall (LBP)

GENERAL INFORMATION

- 33 Vertebrae: 7 cervical, 12 thoracic, 5 lumbar, 5 sacral (fused), 4 coccygeal (fused)
- Vertebrae form a functional column
- 3 column theory (Denis): spine is divided into 3 columns
    - Anterior: ALL & anterior ⅔ of vertebral body/annulus
    - Middle: PLL & posterior ⅓ of vertebral body/annulus
    - Posterior: Pedicles, lamina, spinous process, and ligaments
- Spinal curves: normal curves
    - Cervical lordosis
    - Thoracic kyphosis
    - Lumbar lordosis
    - Sacral kyphosis

Spinal Regions

Cervical	C1-C2: unique bones allow stabilization of occiput to spine and rotation of head. Motion: rotation and flexion/extension.
Thoracic	Relatively stiff due to costal articulations. Motion: rotation. Minimal flexion/extension.
Thoraco-lumbar	Facet orientation transitions from semicoronal to sagittal. Segments are mobile. Most common site of lower spine injuries.
Lumbar	Largest vertebrae. Common site for pain. Houses cauda equina. Motion: flexion/extension. Minimal rotation.
Sacrum	No motion. Is center of pelvis.

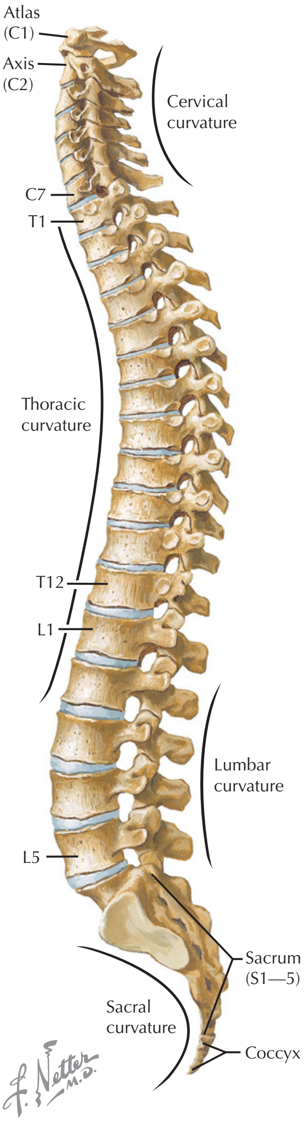
Vertebrae

- Uniquely shaped bones that support the axial musculature and protect the spinal cord and nerve roots

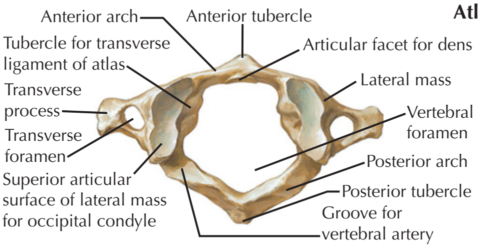
Body (centrum)	Has articular cartilage on both superior & inferior surfaces. Articulates with intervertebral discs & gets larger distally.
Arch	Made up of pedicles and lamina. Develops from 2 ossifications centers that fuse. Failure to fuse occurs in spina bifida. It forms the vertebral canal for the spinal cord.
Processes	Spinous: ligament attachment site. Transverse: rib (T-spine) and ligament attachment site.
Foramina	Vertebral: spinal cord/cauda equina. Neural: nerve roots exit via here.

LEVEL	CORRESPONDING STRUCTURE
C2-3	Mandible
C3	Hyoid cartilage
C4-5	Thyroid cartilage
C6	Cricoid cartilage
C7	Vertebral prominens
T3	Spine of scapula
T7	Xyphoid, tip of scapula
T10	Umbilicus
L1	Conus medullaris (end of cord)
L3	Aorta bifurcation
L4	Iliac crest

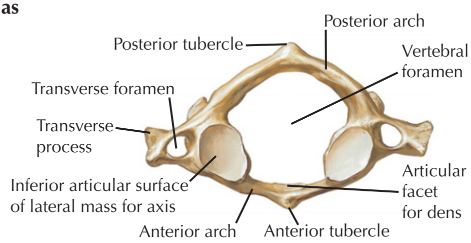
Left lateral view



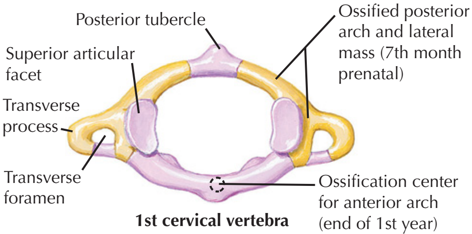
Atlas


Anterior arch
Anterior tubercle
Tubercle for transverse ligament of atlas
Articular facet for dens
Lateral mass
Transverse process
Vertebral foramen
Transverse foramen
Posterior arch
Superior articular surface of lateral mass for occipital condyle
Posterior tubercle
Groove for vertebral artery

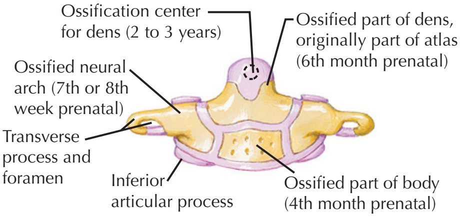
Atlas (C1): superior view


Posterior arch
Posterior tubercle
Vertebral foramen
Transverse foramen
Transverse process
Articular facet for dens
Inferior articular surface of lateral mass for axis
Anterior arch
Anterior tubercle

Atlas (C1): inferior view

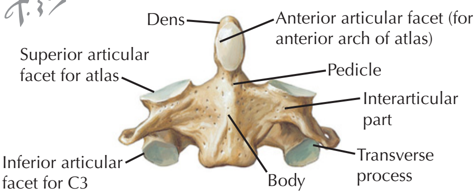

Posterior tubercle
Ossified posterior arch and lateral mass (7th month prenatal)
Superior articular facet
Transverse process
Transverse foramen
Ossification center for anterior arch (end of 1st year)

1st cervical vertebra (atlas) (superior view)

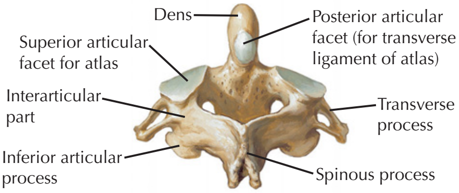

Ossification center for dens (2 to 3 years)
Ossified part of dens, originally part of atlas (6th month prenatal)
Ossified neural arch (7th or 8th week prenatal)
Transverse process and foramen
Inferior articular process
Ossified part of body (4th month prenatal)

2nd cervical vertebra (axis) (anterior view)

Axis


Dens
Anterior articular facet (for anterior arch of atlas)
Superior articular facet for atlas
Pedicle
Interarticular part
Transverse process
Inferior articular facet for C3
Body

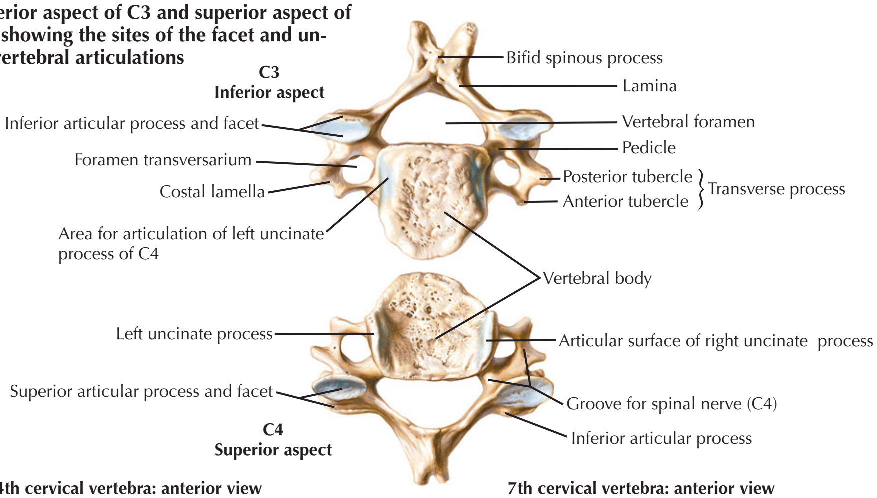
Axis (C2): anterior view


Dens
Posterior articular facet (for transverse ligament of atlas)
Superior articular facet for atlas
Interarticular part
Transverse process
Inferior articular process
Spinous process

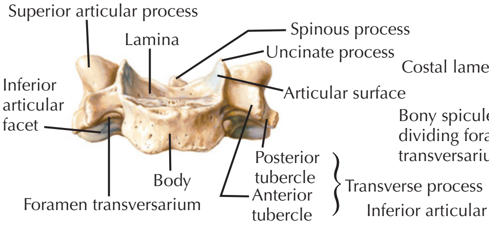
Axis (C2): posterosuperior view

CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
		CERVICOCRANIUM		
		Atlas (C1)		
• Ring shaped • 2 lateral masses with facets; facets are concave • 2 arches connect lateral masses: ◦ anterior tubercle ◦ posterior tubercle • Transverse process has a foramen	Lateral masses/ posterior arch Body/anterior arch	7mo fetal to birth 6-12mo	3-4yr 7yr	• Ring/arches are susceptible to fracture • Superior facets (concave) articulate with occiput; inferior facets articulate with C2 • Posterior arch has groove for vertebral artery • Attachment site of ALL and longus colli • Attachment site of ligamentum nuchae • Vertebral artery through foramen transversarium
		Axis (C2)		
• Body • Odontoid process (dens) • Lateral masses with facets and two small transverse processes • Pedicles (between facets) • Spinous process	**Primary** Body Lateral mass/ neural arch [2] Odontoid—Body Tip	 4mo fetal 7mo fetal 6mo fetal 2-3 yr	 3-7yr 2-yr 3-6yr 12yr	• Odontoid projects superiorly & allows C1-C2 rotation; primary horizontal stabilizer • Concave superior facets allow for rotation • Vertebral artery through foramen transversarium • Pedicles (isthmus) susceptible to fracture • Bifid, relatively large and palpable
There are two secondary ossification centers in the axis: ossiculum terminale and inferior ring apophysis.				

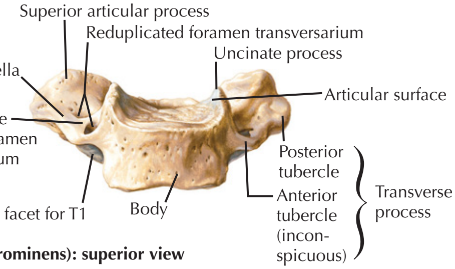
Inferior aspect of C3 and superior aspect of C4 showing the sites of the facet and uncovertebral articulations


C3
Inferior aspect
Bifid spinous process
Lamina
Inferior articular process and facet
Vertebral foramen
Pedicle
Foramen transversarium
Posterior tubercle
Anterior tubercle
Transverse process
Costal lamella
Area for articulation of left uncinate process of C4
Vertebral body
Left uncinate process
Articular surface of right uncinate process
Superior articular process and facet
Groove for spinal nerve (C4)
C4
Superior aspect
Inferior articular process

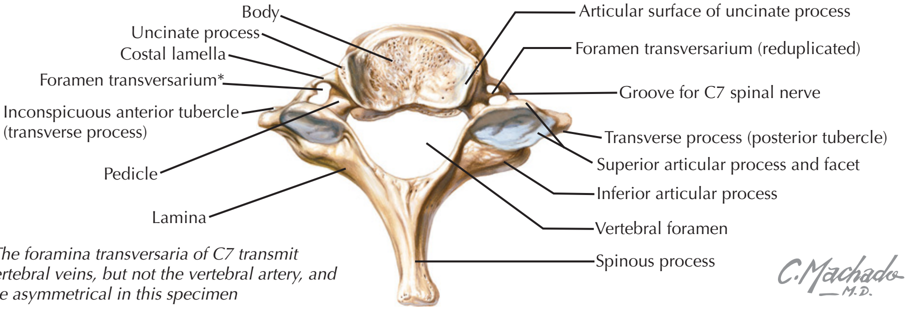
4th cervical vertebra: anterior view


Superior articular process
Lamina
Spinous process
Uncinate process
Inferior articular facet
Articular surface
Posterior tubercle
Anterior tubercle
Transverse process
Body
Foramen transversarium

7th cervical vertebra: anterior view

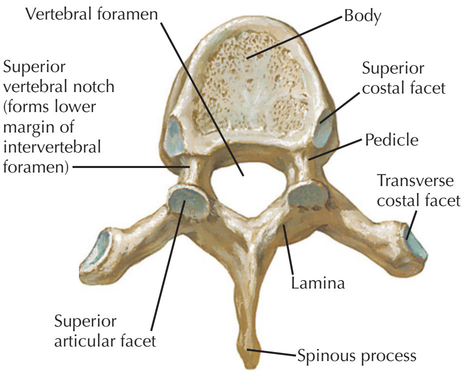

Superior articular process
Reduplicated foramen transversarium
Uncinate process
Costal lamella
Articular surface
Bony spicule dividing foramen transversarium
Posterior tubercle
Anterior tubercle (inconspicuous)
Transverse process
Inferior articular facet for T1
Body

7th cervical vertebra (vertebra prominens): superior view

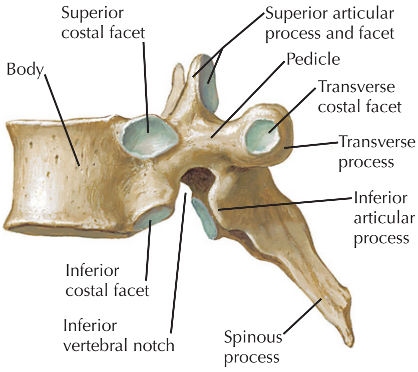

Body
Uncinate process
Costal lamella
Foramen transversarium*
Inconspicuous anterior tubercle (transverse process)
Pedicle
Lamina
Articular surface of uncinate process
Foramen transversarium (reduplicated)
Groove for C7 spinal nerve
Transverse process (posterior tubercle)
Superior articular process and facet
Inferior articular process
Vertebral foramen
Spinous process
C.Machado M.D.

**The foramina transversaria of C7 transmit vertebral veins, but not the vertebral artery, and are asymmetrical in this specimen*

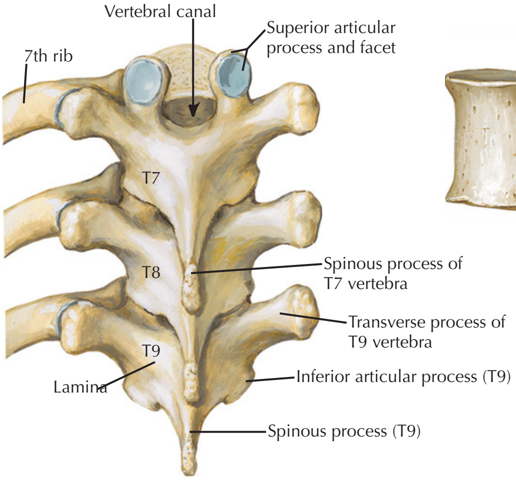
CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
		CERVICAL (C3-7)		
• Body	**Primary**			• Concave superiorly, convex inferiorly
• Uncinate processes [2]	Body/centrum	7-8wk fetal	6yr	• Articulates with adjacent vertebral body
• Small pedicles	Neural arch [2]		5-8yr	• Angled medial & superior, too small for screws
• Transverse processes	**Secondary**			• Have foramen for vertebral artery except C7
• Lateral masses—2 facets	Spinous process	12-15yr	25yr	• Can accept screws if angled laterally (artery at risk in foremen)
• Facets (superior & inferior)	Transverse process [2]			• "Semi-coronal" orientation allows for flexion/extension
• Lamina	Annular (ring) epiphysis [2]			• Connects lateral masses to spinous process
• Spinous process				• Usually bifid (C3-5), C7 is the largest


Vertebral foramen
Body
Superior vertebral notch (forms lower margin of intervertebral foramen)
Superior costal facet
Pedicle
Transverse costal facet
Lamina
Superior articular facet
Spinous process

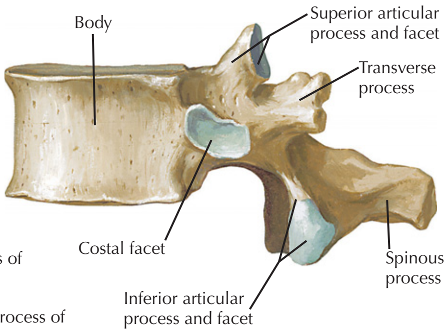
T6 vertebra: superior view


Superior costal facet
Superior articular process and facet
Body
Pedicle
Transverse costal facet
Transverse process
Inferior articular process
Inferior costal facet
Inferior vertebral notch
Spinous process

T6 vertebra: lateral view

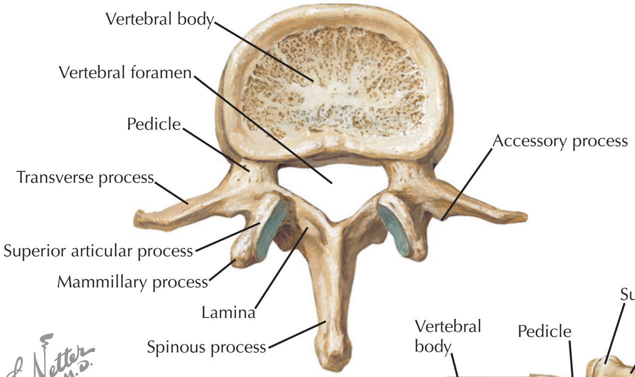

Vertebral canal
Superior articular process and facet
7th rib
T7
T8
T9
Spinous process of T7 vertebra
Transverse process of T9 vertebra
Inferior articular process (T9)
Lamina
Spinous process (T9)

T7, T8, and T9 vertebrae: posterior view

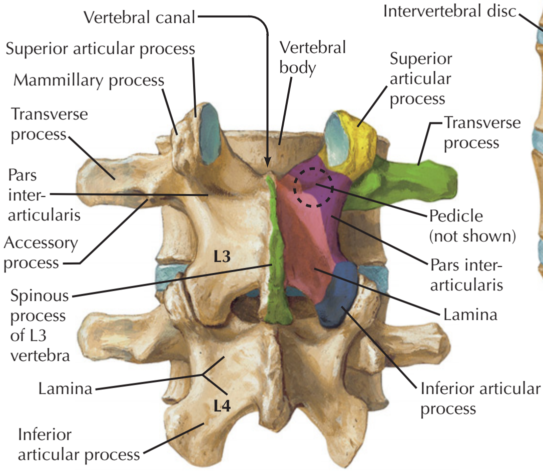

Body
Superior articular process and facet
Transverse process
Costal facet
Spinous process
Inferior articular process and facet

T12 vertebra: lateral view

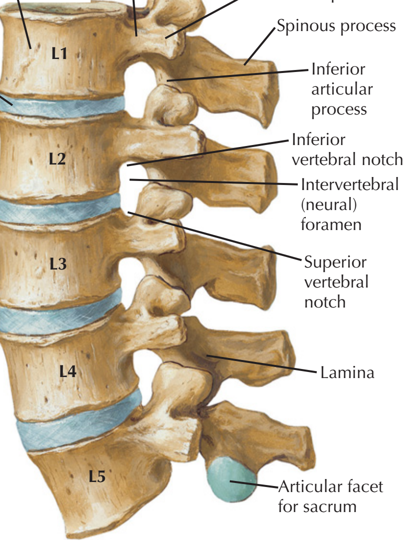
CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
	THORACIC			
• Body: costal facets (articulate w/ ribs) • Pedicles: increase in size in lower T-spine • Articular processes/ facets • Transverse process • Lamina • Spinal process	**Primary** Body/centrum Neural arch [2] **Secondary** Spinous process Transverse process [2] Annular (ring) epiphysis [2]	7-8wk fetal 12-15yr	6yr 5-8yr 25yr	• Upper thoracic have superior & inferior facets; lower thoracic have a single facet. • Can accept screws for spinal fixation, have anteromedial orientation. • Facets are semicoronal, allow for rotation but minimal flexion/extension • Have costal facet in upper T-spine • Broad & overlapping (like shingles) • Long with steep posterior slope
Landmark for pedicle screw: junction of lines through upper ⅓ transverse process and just lateral to vertical line through facet				


Vertebral body
Vertebral foramen
Pedicle
Transverse process
Superior articular process
Mammillary process
Lamina
Spinous process
Accessory process

L2 vertebra: superior view

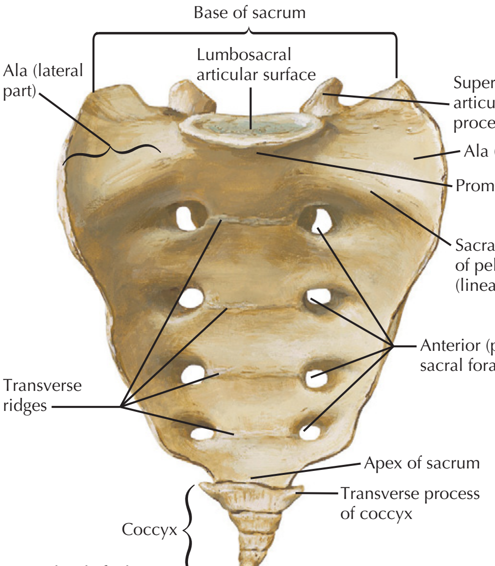

Vertebral canal
Superior articular process
Mammillary process
Transverse process
Pars inter-articularis
Accessory process
Spinous process of L3 vertebra
Lamina
Inferior articular process
Vertebral body
L3
L4
Superior articular process
Transverse process
Pedicle (not shown)
Pars inter-articularis
Lamina
Inferior articular process

L3 and L4 vertebrae: posterior view


Intervertebral disc
Vertebral body
Pedicle
Superior articular process
Mammillary process
Transverse process
Spinous process
Inferior articular process
Inferior vertebral notch
Intervertebral (neural) foramen
Superior vertebral notch
Lamina
Articular facet for sacrum
L1
L2
L3
L4
L5

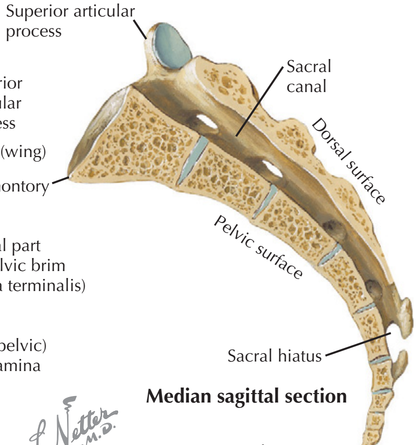
Lumbar vertebrae, assembled: left lateral view

CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
		LUMBAR		
• Body: large • Pedicles: large, short, but strong • Articular processes/ facets: has a mammillary process • Pars interarticularis • Transverse process • Lamina • Spinous process	**Primary** Body/centrum Neural arch [2] **Secondary** Mammillary proc. Ring epiphysis [2] Transverse process [2] Spinous process	 7-8wk fetal 12-15yr	 6yr 5-8yr 25yr	• Broad, oval, cylindrical shaped bone • Orientation changes through L-spine; this portion of bone accepts screw fixation • Sagittal orientation allows flexion/extension • Superior facets are lateral to inferior facets/articular processes • Area b/w facets, site of spondylolysis/fx • Avulsion fracture can occur here. • Do not overlap adjacent levels • Long, palpable posteriorly
Landmark for pedicle screw: junction lines through middle of transverse process and lateral border of facet joint. Failure of fusion of two neural arch (pedicle/lamina) ossification centers results in spina bifida.				

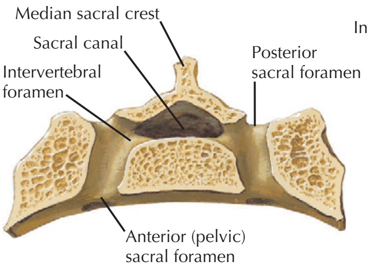

Base of sacrum
Lumbosacral articular surface
Ala (lateral part)
Superior articular process
Ala (wing)
Promontory
Sacral part of pelvic brim (linea terminalis)
Anterior (pelvic) sacral foramina
Transverse ridges
Apex of sacrum
Transverse process of coccyx
Coccyx

Anterior inferior view

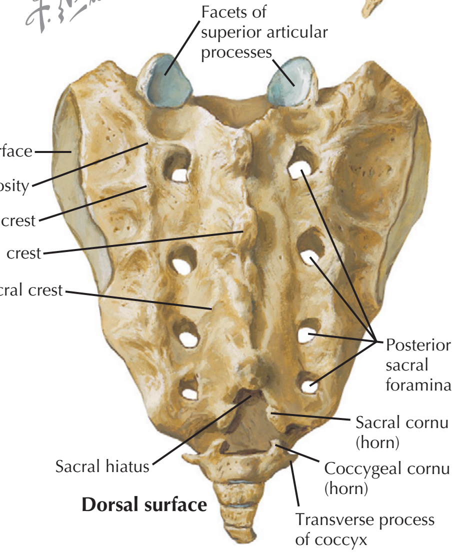
Pelvic surface


Superior articular process
Sacral canal
Dorsal surface
Pelvic surface
Sacral hiatus
F. Netter M.D.

Median sagittal section


Median sacral crest
Sacral canal
Intervertebral foramen
Posterior sacral foramen
Anterior (pelvic) sacral foramen

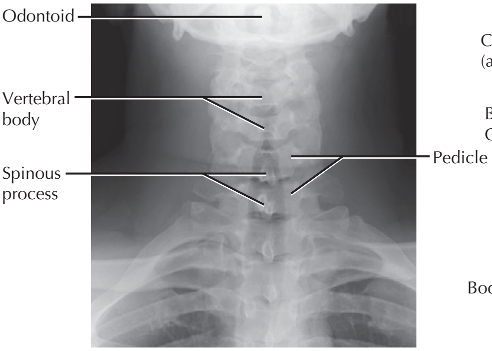
Coronal section through S1 foramina


Facets of superior articular processes
Auricular surface
Sacral tuberosity
Lateral sacral crest
Median sacral crest
Intermediate sacral crest
Posterior sacral foramina
Sacral cornu (horn)
Coccygeal cornu (horn)
Transverse process of coccyx
Sacral hiatus

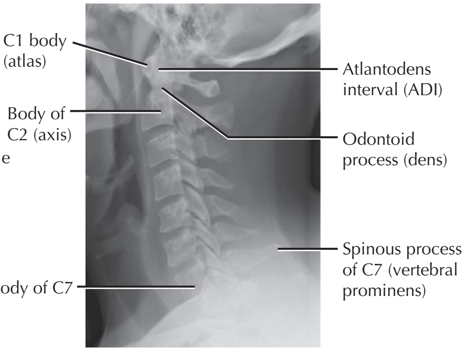
Dorsal surface

Posterior superior view

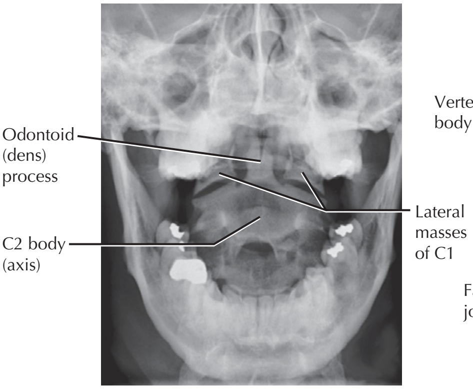
CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
		SACRUM		
• 5 vertebrae are fused • 4 pairs of foramina (left and right) • Ala (wing) expands laterally • Kyphotic (approx 25°), apex at S3 • Sacral canal opens to hiatus distally	**Primary** Body Arches Costal **Secondary**	 7-8wk fetal 11-14yr	 2-8yr 12-18yr	• Transmits body weight from spine to pelvis • Nerves exit through sacral foramina • Ala is common site for sacral fractures • Sacral canal narrows distally • Segments fuse to each other at puberty
		COCCYX		
• 4 vertebrae are fused • Lack features of typical vertebrae • Bones become smaller distally	**Primary** Body Arches	 7-8wk fetal	 1-2yr 7-10yr	• Attached to gluteus maximus and coccygeal muscle • No neural foramen; distal to sacral hiatus • Common site for "tailbone" fracture


Odontoid
Vertebral body
Spinous process
Pedicle

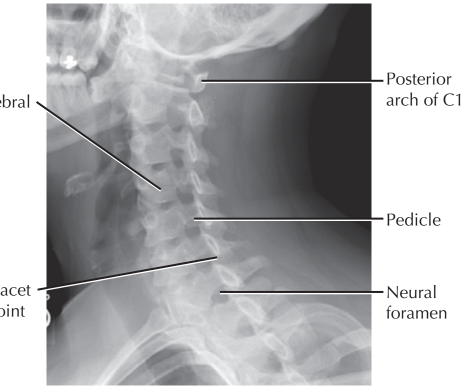
C-spine x-ray, AP


C1 body (atlas)
Body of C2 (axis)
Body of C7
Atlantodens interval (ADI)
Odontoid process (dens)
Spinous process of C7 (vertebral prominens)

C-spine x-ray, lateral


Odontoid (dens) process
C2 body (axis)
Lateral masses of C1

C-spine x-ray, odontoid

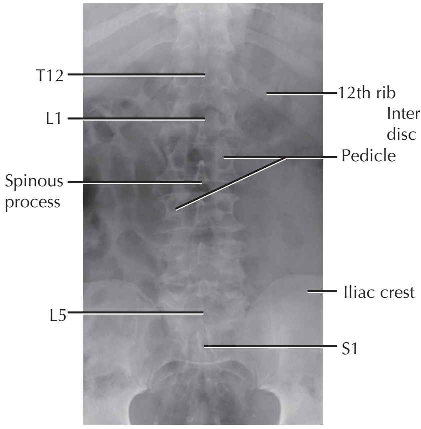

Vertebral body
Facet joint
Posterior arch of C1
Pedicle
Neural foramen

C-spine x-ray, oblique

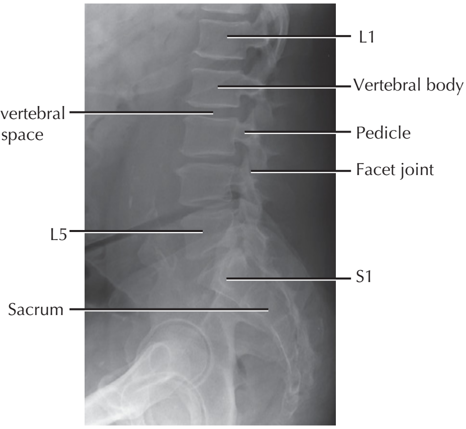
RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
CERVICAL SPINE			
AP (anteroposterior)	Erect/supine, beam w/slight cephalad tilt at mid C-spine	Vertebral bodies (esp. C3-7), intervertebral disc spaces	Cervical fractures, spondylosis
Lateral (crosstable)	Supine, horizontal beam to mid C-spine (must see C7)	Bodies, disc space, facets 4 lines: 1. Ant. vert. (ALL); 2. Post. vert. (PLL); 3. Spinolaminar (ligamentum flavum); 4. Post. spinous	First x-ray in all trauma cases Fractures & dislocations. Increased retropharyngeal swelling (>6mm at C2 or >22mm at C6) may indicate fx
Odontoid (open mouth)	Beam into open mouth	Odontoid, lateral masses	C1 (Jefferson) or C2/odontoid fx
Swimmer's view	Prone, one arm above head, beam into axilla	C7, T1, and T2	Used if lateral does not show C7 Used to rule out cervical fractures
Obliques	AP, turn body 45°	Neural foramina & facet joints	Foraminal stenosis
Flexion/extension views	Lateral with flexion/ extension	Same as lateral	For instability/spondylolisthesis

Multiple measurements can be made from the lateral C-spine radiograph

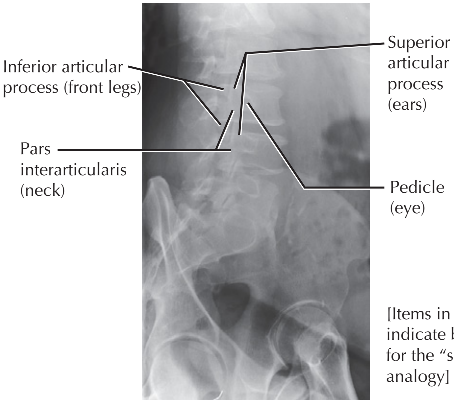
1. ADI (atlantodens interval): Posterior aspect of C1 anterior arch to anterior border of odontoid. Normal is ≤3mm
2. SAC (space available for cord): Posterior odontoid to anterior aspect of posterior arch: Normal = 17mm
3. Power ratio: Basion (B) to C1 post. arch (C), opisthion (O) to C1 ant. arch (A). Ratio BC/OA >1 = occipitoatlantal dx
4. Chamberlain's line: Opisthion to hard palate. Odontoid tip ≤5mm above line. >5mm is basilar invagination


T12
L1
Spinous process
L5
12th rib
Pedicle
Iliac crest
S1

Lumbar x-ray, AP

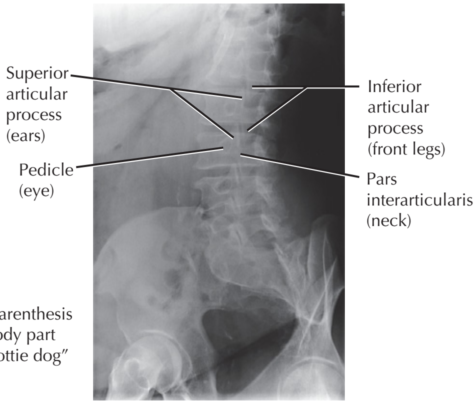

Intervertebral disc space
L5
Sacrum
L1
Vertebral body
Pedicle
Facet joint
S1

Lumbar x-ray, lateral


Inferior articular process (front legs)
Pars interarticularis (neck)
Superior articular process (ears)
Pedicle (eye)

Lumbar x-ray, oblique

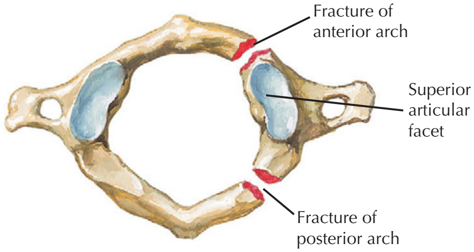
[Items in parenthesis indicate body part for the "scottie dog" analogy]


Superior articular process (ears)
Pedicle (eye)
Inferior articular process (front legs)
Pars interarticularis (neck)

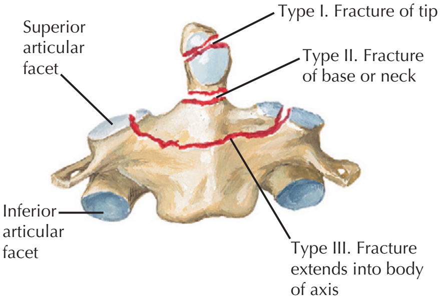
Lumbar x-ray, oblique

RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
		THORACIC SPINE	
AP (anteroposterior)	Supine, beam to mid T-spine	Vertebral bodies	Alignment, scoliosis (Cobb angle)
Lateral	Lateral, beam to T-spine	Bodies & posterior elements	Alignment, kyphosis, scoliosis, fx
Bending films	AP or lateral w/ bending	Thoracic vertebrae	Access flexibility of scoliosis curves
		LUMBAR SPINE	
AP (anteroposterior)	Supine, flex hips, beam @L3	Bodies, disc spaces, pedicle position, transverse process	Fracture (body-pedicle widening, transverse process), dislocation
Lateral	Lateral, flex hips, beam @L3	Bodies, pars, disc spaces	Fractures, spondylolisthesis
Obliques	AP, turn body 45°	Neural foramina, pars interarticularis, facet joints	Foraminal stenosis, spondylosis, facet hypertrophy (DJD)
Flexion/extension views	Lateral with flexion/ extension	Same as lateral	Instability/spondylolisthesis

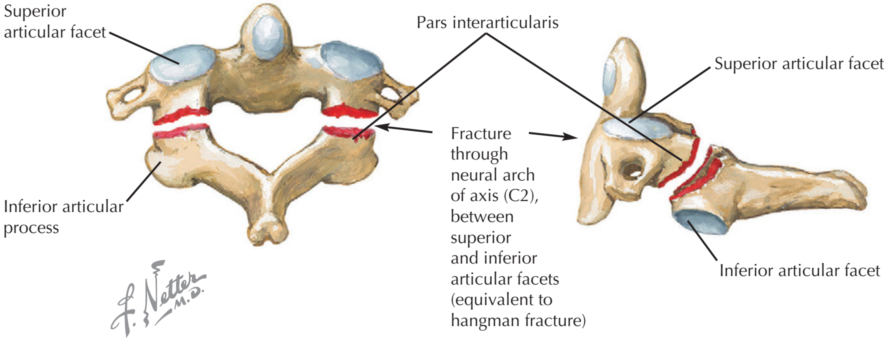
Jefferson fracture of atlas (C1)
Each arch may be broken in one or more places


Fracture of anterior arch
Superior articular facet
Fracture of posterior arch

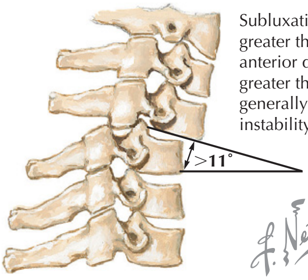
Fracture of odontoid process


Superior articular facet
Type I. Fracture of tip
Type II. Fracture of base or neck
Inferior articular facet
Type III. Fracture extends into body of axis

Traumatic spondylolisthesis

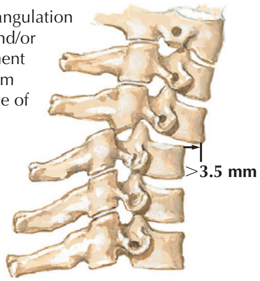

Superior articular facet
Pars interarticularis
Superior articular facet
Fracture through neural arch of axis (C2), between superior and inferior articular facets (equivalent to hangman fracture)
Inferior articular process
Inferior articular facet
F. Netter M.D.

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
CERVICOCRANIUM INJURIES			
• Injuries to this region can be both subtle and devastating • ATLS protocols warranted • Occipital/cervical dx: high mortality, increased incidence in pediatric patients • Atlantoaxial instability: disruption of transverse ligament [TAL] +/− alar & apical ligaments determine degree of instability • Type 2 odontoid fractures have high nonunion rate • Traumatic spondylolisthesis is bilateral pars fracture (similar to hangman's fx, but different mechanism)	**Hx:** High-energy trauma, (e.g., MVA, fall, diving), +/− pain, numbness, tingling, weakness **PE:** Stabilize head & neck Inspect & palpate neck Neuro exam: CN's, UE & LE motor/sensory/reflexes **XR:** Lateral, odontoid, AP basion to dens ≤5mm Power's ratio <1 is normal; ADI ≤3mm is normal; flexion/extension views: to evaluate dynamic instability **CT:** Best for all fractures **MR:** Ligaments, cord, roots	**Occipitocervical dissociation** **Atlantoaxial instability:** 1. midsubstance, 2. avulsion **C1** (atlas) (7 types): burst (3-4 fx, Jefferson)[1], post. arch [2], comminuted [3], ant. arch [4], lat. mass [5], transv. proc.[6], inf. tubercle [7] **C2** (axis): ◦ **Odontoid fx:** type 1: tip, type 2: base (jxn dens/body), type 3: C2 body ◦ **Traumatic spondylolisthesis:** 1. nondisplaced, 2. displaced & angulated, 2a. angulated, 3. fx w/ C2-3 facet dx	• O-C dx: halo vs fusion • C1-C2: ADI <5mm: collar • ADI >5mm: C1-2 fusion • C1 fracture: ◦ Unstable/wide: C1-2 fusion ◦ Stable: halo vs collar immobilization 3mo • Avulsion: soft collar 6wk • C2 fracture: • Odontoid: ◦ Collar ◦ ORIF(displaced) vs halo (nondisplaced) ◦ Halo vest • Traumatic spondylolisthesis ◦ Collar immobilization ◦ CR/halo vs ORIF ◦ ORIF (C2 screws)
COMPLICATIONS: Nonunion (esp. odontoid type 2); neurologic (cord trauma); persistent pain, instability, or stiffness			



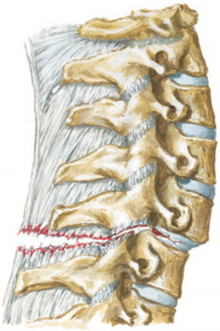
Subluxation with angulation greater than 11° and/or anterior displacement greater than 3.5 mm generally indicative of instability

Subluxation with angulation greater than 11°

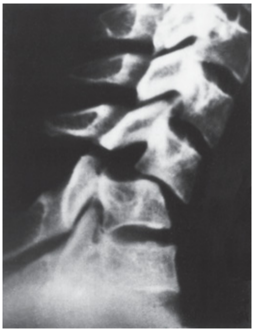


Anterior displacement greater than 3.5 mm

Facet dislocation



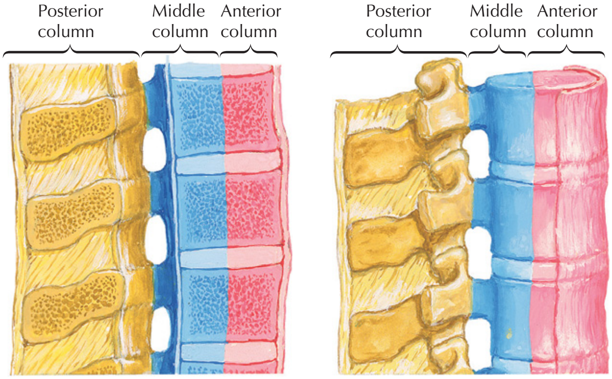
Anterior facet dislocation of C5 on C6 with tear of interspinous ligament, facet capsules, and posterior fibers of intervertebral disc



X-ray (lateral view) shows bilateral facet dislocation at C5–C6

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
SUBAXIAL CERVICAL FRACTURES			
• Compression fx: involve ant. half of vertebral body • Burst fx: involve whole vertebral body & have retropulsion into spinal canal • Instability (White & Panjabi) ◦ >3.5mm of translation ◦ >11° kyphotic angulation ◦ + stretch test ◦ Neuro (cord or root) injury ◦ Ant. elements destroyed ◦ Post. elements destroyed ◦ Narrow spinal canal ◦ Disc space narrowing • Heavy loads anticipated	**Hx:** High-energy trauma, (e.g., MVA, fall, diving), +/− pain, numbness, tingling or weakness **PE:** Stabilize head & neck Palpate neck for "step off." Neuro exam: CN's, UE & LE motor/sensory/ reflexes **XR:** Lateral, odontoid, AP Evaluate for stability criteria Flexion/extension views: to evaluate dynamic instability **CT:** Best study for all fractures **MR:** Assess posterior ligaments & for disc herniation on cord	**By mechanism** (each class is subclassified by severity) 1. Flexion-compression [#1] 2. Vertical compression 3. Flexion-distraction [#2] 4. Extension-compression 5. Extension-distraction 6. Lateral flexion **Descriptive** Compression Burst Facet dislocation Unilateral Bilateral	• Compression fx: collar • Burst fx: ACDF (anterior corpectomy, diskectomy, and fusion [ant. plate]) vs decompression/post. fusion) • Flexion-compression: ◦ Stable: collar or halo; ◦ Unstable: ant. or post. fusion • Flexion-distraction/ facet dx: Closed (acute, awake pt) vs open (unconscious or late presentation) reduction with anterior (ACDF) or posterior spinal fusion
COMPLICATIONS: Neurologic: quadriplegia, paraplegia, radiculopathy. Vascular: vertebral artery. Immobilization: halo.			

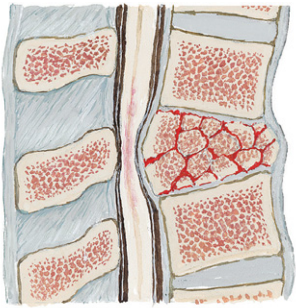
Three-Column Concept of Spinal Stability



Three-column concept. If more than one column involved in fracture, then instability of spine usually results

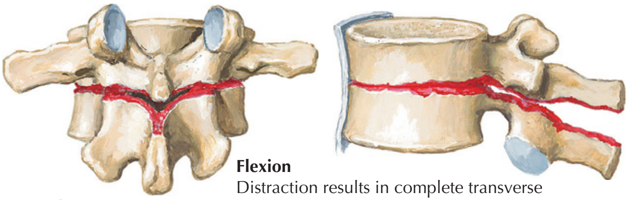
Lateral view. Note that lateral facet (zygapophyseal) joints in posterior column, with intervertebral foramina in middle column

Burst fracture



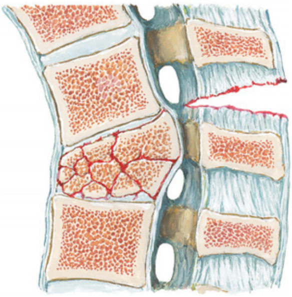
Burst fracture of unstable vertebral body involving both anterior and middle columns resulted in instability and spinal cord compression

Chance fracture



Flexion

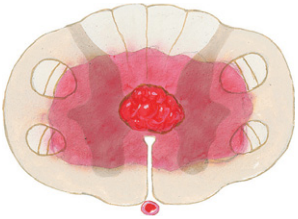
Distraction results in complete transverse fracture through entire vertebra. Note hinge effect of anterior longitudinal ligament

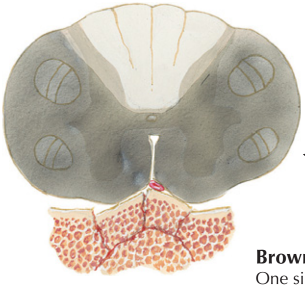


Fracture/Dislocation:
All 3 columns are involved

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
THORACOLUMBAR FRACTURES			
• Mechanism: MVA or fall (lap belt can be fulcrum to cause flexion-distraction fx) • Thoracolumbar junction is most common site of fracture/injury • Determining stability is key to treatment • 3-column theory (Denis): >1 column injured = unstable • Burst fx: caused by 1. flexion and 2. axial compression • Chance fx: flexion-distraction fx, all 3 columns fail in tension	**Hx:** High-energy trauma, pain +/− numbness or weakness **PE:** Palpate for "step off" Neuro exam: LE motor/sensory/reflexes (including anal wink & bulbocavernosus) **XR:** Lateral (body ht, kyphosis) AP (pedicle widening) Flexion/extension views: to evaluate dynamic instability **CT:** Best study for all fractures Evaluate for retropulsion **MR:** Discs & post. ligaments	**Compression:** 1 (anterior) column only, stable fx **Stable burst:** 2 columns 1. <25° kyphosis 2. <50% body ht loss 3. <50% canal retropulsion **Unstable burst:** 2-3 columns fail above criteria or have neurologic compromise **Flexion-distraction:** 2-3 columns; columns fail posterior to anterior **Translation** (fx/dx): All 3 columns fail: unstable	• Compression: observation or orthosis 12wk • Stable burst: TLSO or hyperextension brace for 12wk (f/u x-rays to confirm stability) • Unstable burst: decompression & posterior spinal fusion • Flexion-distraction: most require posterior fusion • Translation: needs reduction and stabilization/fusion
COMPLICATIONS: Neurologic: Spinal cord/cauda equina injury. Immobilization: DVT, PE. Surgical: Infection, dural tears.			

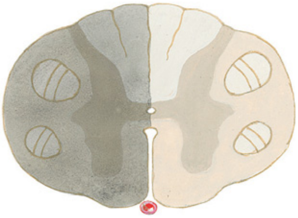
Central cord syndrome
Central cord hemorrhage and edema. Parts of 3 main tracts involved on both sides. Upper limbs more affected than lower limbs ▷





Anterior spinal artery syndrome
Artery damaged by bone or cartilage spicules (shaded area affected). Bilateral loss of motor function and pain sensation below injured segment; position sense preserved ◁

Brown-Sequard syndrome
One side of cord affected. Loss of motor function and position sense on same side and of pain sensation on opposite side ▷



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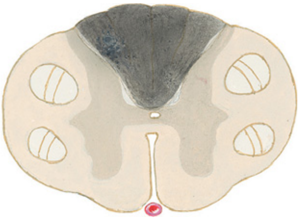
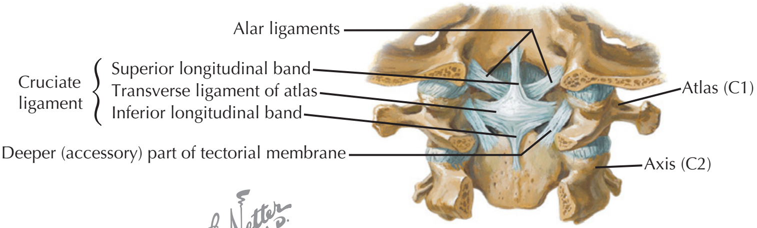
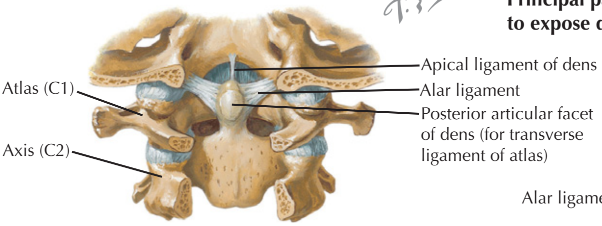


Posterior column syndrome (uncommon)
Position sense lost below lesion; motor function and pain sensation preserved ◁

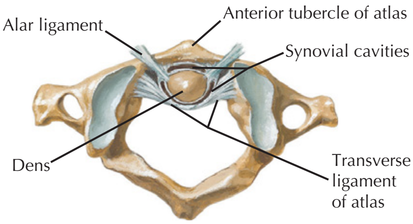
DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
SPINAL CORD TRAUMA			
• Young males most common • High association w/C-spine fractures (easily missed) • Central: #1, hyperextension mechanism, seen in elderly, with cervical spondylosis • Anterior: #2, worst prognosis • Brown-Sequard: usually penetrating trauma, rare injury, best prognosis • Posterior: very rare; this pattern may not exist	**Hx:** High-energy trauma (MVA, fall), +/− numbness or weakness **PE:** Find lowest functional neurologic level Central: UE>LE motor loss Anterior: LE>UE motor and sensory, proprioception intact B-S: Ipsilateral motor loss, contralateral pain/temp loss **XR:** r/o C-spine fx **CT:** r/o or evaluate C-spine fx **MR:** Shows cord, disc herniation (on cord), posterior ligaments	• **Complete:** no function below the injured level (spinal shock must be resolved to diagnose) • **Incomplete:** partial sparing of distal function ◦ **Central:** central gray matter ◦ **Anterior:** Spinothalamic & corticospinal tracts out, posterior columns spared ◦ **Brown-Sequard:** lateral half of spinal cord ("hemisection") ◦ **Posterior:** posterior columns	• Methylprednisolone IV given within 8hr of injury may improve functional level • Most patients recover 1 (or 2) levels of function in complete injuries • Decompression of cord (reduce dislocations or remove bone fragments) with internal or external (e.g., collar or halo) immobilization
COMPLICATIONS: Neurologic; autonomic dysreflexia (treat with urinary catheter/rectal disimpaction); spinal instability.			
• Spinal shock: Paralysis/areflexia from physiologic cord injury. Return of bulbocavernosus reflex is end of spinal shock. • Neurogenic shock: Hypotension with bradycardia. Decreased sympathetic (unopposed vagal) tone. Treat with vasopressors. • Hypovolemic shock: Hypotension with tachycardia. Treat with fluid/volume resuscitation.			


Alar ligaments
Cruciate ligament
Superior longitudinal band
Transverse ligament of atlas
Inferior longitudinal band
Deeper (accessory) part of tectorial membrane
Atlas (C1)
Axis (C2)

Principal part of tectorial membrane removed to expose deeper ligaments: posterior view

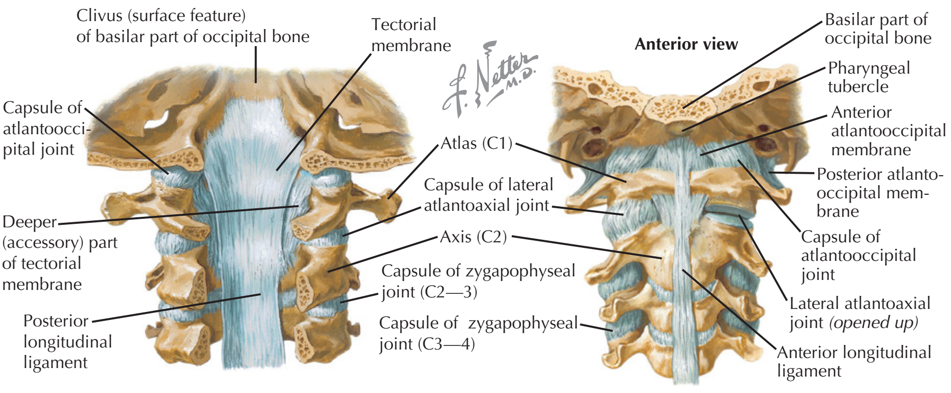

Atlas (C1)
Axis (C2)
Apical ligament of dens
Alar ligament
Posterior articular facet of dens (for transverse ligament of atlas)

Cruciate ligament removed to show deepest ligaments: posterior view


Alar ligament
Anterior tubercle of atlas
Synovial cavities
Dens
Transverse ligament of atlas

Median atlantoaxial joint: superior view

LIGAMENT	ATTACHMENTS	COMMENTS
OCCIPITOATLANTAL JOINT		
• Articulation between convex occipital condyles and concave superior facets of atlas (C1). This articulation is horizontal (especially in pediatrics) allowing for rotation, but is inherently horizontally unstable. ROM: flexion/extension 25°; lateral bending 5° (each side); rotation 5° (each side).		
Capsule	Surrounds joints (condyle & facet)	Loose tissue provides minimal stability
Ant. atlantooccipital	Ant. atlas arch to ant. foramen mag.	Continuation of ALL
Tectorial membrane	Post. axis to ant. foramen magnum	Primary stabilizer. Continuation of PLL, limits extension
Post. atlantooccipital	Post. arch to post. foramen magnum	Homologous to ligamentum flavum
ATLANTOAXIAL JOINT (C1-2)		
• Made up of 3 articulations: Central (median) atlantoaxial joint (pivot type): between the odontoid and anterior arch. Lateral atlantoaxial joints [2] (plane type): between the articulating facets of atlas and axis, allow for rotation. ROM: flex/extend 20º; lateral bending 5º (each side); rotation 40º (each side). Supplies 50% of cervical rotation.		
Capsule	Surrounds lateral facet joints	Loose capsule allows for rotation
Cruciate **Transverse atlantal** (TAL) Superior longitudinal Inferior longitudinal	 Posterior odontoid to anterior arch Odontoid to ant. foramen magnum Odontoid to body of axis	Has 3 components, is anterior to tectorial membrane Strongest ligament, holds odontoid to atlas. ADI <3mm. Injury results in C1-2 instability. Posterior to apical ligament, secondary stabilizer. Secondary stabilizer
Alar	Odontoid to occipital condyles	Strong, stabilizing ligaments, limit rotation & lateral bending. Injury results in C1-2 instability.
Apical	Odontoid to ant. foramen magnum	Thin ligament provides minimal stability
Accessory	Axis body to occipital condyles	Secondary stabilizers


Clivus (surface feature) of basilar part of occipital bone
Tectorial membrane
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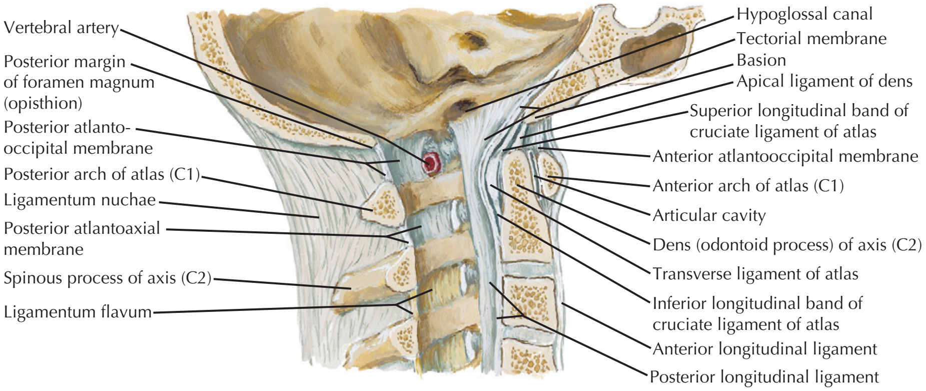
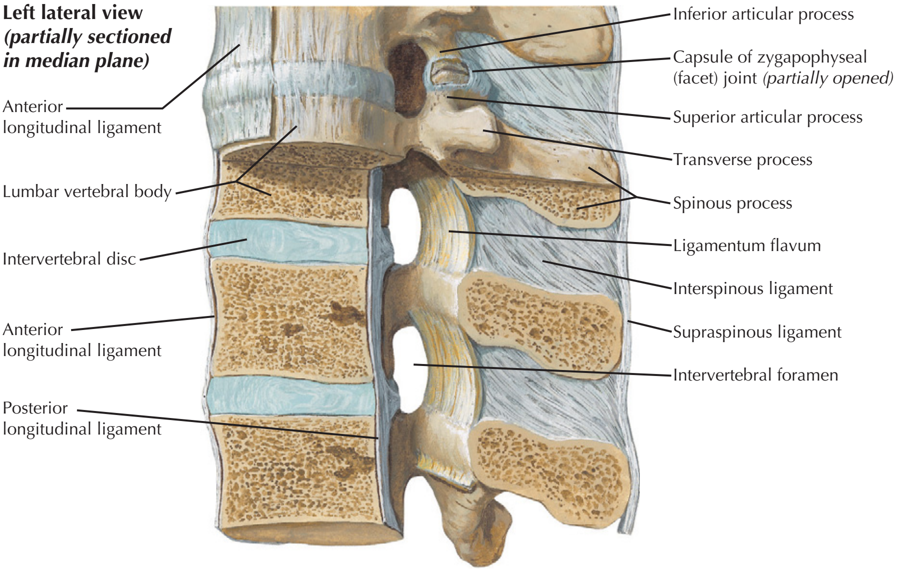
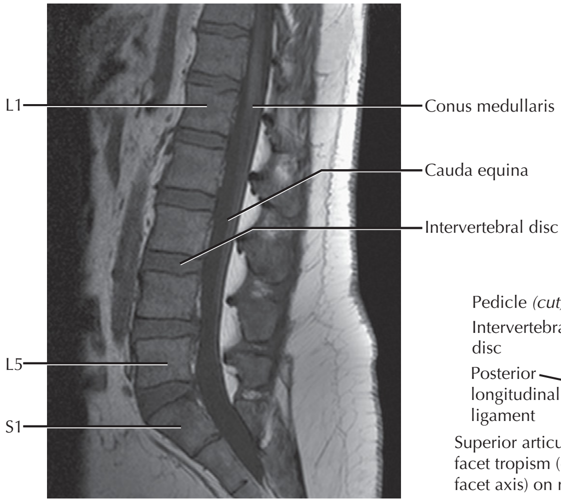
Capsule of atlantooccipital joint
Deeper (accessory) part of tectorial membrane
Posterior longitudinal ligament
Atlas (C1)
Capsule of lateral atlantoaxial joint
Axis (C2)
Capsule of zygapophyseal joint (C2—3)
Capsule of zygapophyseal joint (C3—4)
Anterior view
Basilar part of occipital bone
Pharyngeal tubercle
Anterior atlantooccipital membrane
Posterior atlanto-occipital membrane
Capsule of atlantooccipital joint
Lateral atlantoaxial joint *(opened up)*
Anterior longitudinal ligament

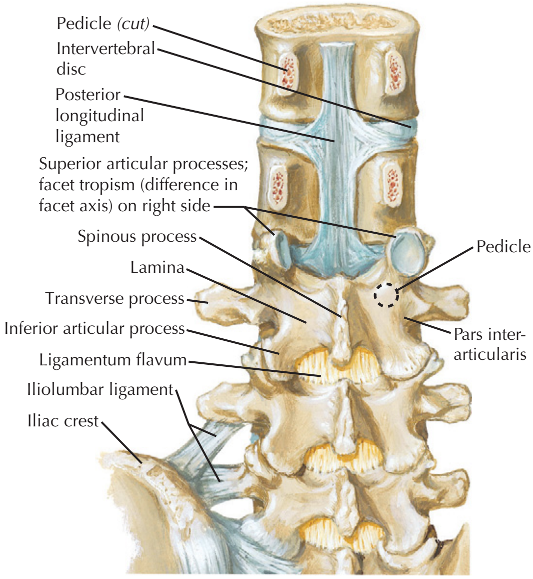

Vertebral artery
Posterior margin of foramen magnum (opisthion)
Posterior atlanto-occipital membrane
Posterior arch of atlas (C1)
Ligamentum nuchae
Posterior atlantoaxial membrane
Spinous process of axis (C2)
Ligamentum flavum
Hypoglossal canal
Tectorial membrane
Basion
Apical ligament of dens
Superior longitudinal band of cruciate ligament of atlas
Anterior atlantooccipital membrane
Anterior arch of atlas (C1)
Articular cavity
Dens (odontoid process) of axis (C2)
Transverse ligament of atlas
Inferior longitudinal band of cruciate ligament of atlas
Anterior longitudinal ligament
Posterior longitudinal ligament

LIGAMENT	ATTACHMENTS	COMMENTS
INTERVERTEBRAL ARTICULATION		
Adjacent vertebrae are joined by a complex of smaller joints/articulations, ligaments, muscles, & connecting structures. • An intervertebral disc lies between the vertebral bodies (except b/w C1-2 and b/w the fused sacral segments). • Paired facet (apophyseal) joints connect the posterior elements. Their orientation dictates that intervertebral motion. • Uncovertebral joints (of Luschka) add stability between vertebral bodies in the cervical spine.		
Intervertebral disc	To adjacent vertebral bodies	Annulus gives strong connection b/w adjacent bodies
Anterior longitudinal ligament (ALL)	Adjacent anterior vertebral bodies and discs	Strong, thick ligament. Resists hyperextension.
Posterior longitudinal ligament (PLL)	Adjacent posterior vertebral bodies & discs (full length of spine)	Weak, limits hyperflexion. Disc herniates around ligament. Tectorial membrane is the superior continuation.
Ligamentum flavum	Anterior lamina (superior vert.) to posterior lamina (inferior vert.)	Strong, yellow, not a long continuous structure. Hypertrophy may contribute to nerve root impingement.
Ligamentum nuchae	Occipital protuberance to C1 post. arch & C2-C6 spinous processes	Continuation of supraspinous ligament
Supraspinous	Dorsal spinous processes to C7	Strong. Ligamentum nuchae is its superior continuation.
Interspinous	Between spinous processes	Weak. Torn in ligamentous flexion-distraction injuries.
Intertransverse	Between transverse processes	Weak ligament, adds little support.
Iliolumbar	L5 transverse process to ilium	May avulse in pelvic fracture (e.g., vertical shear fx).

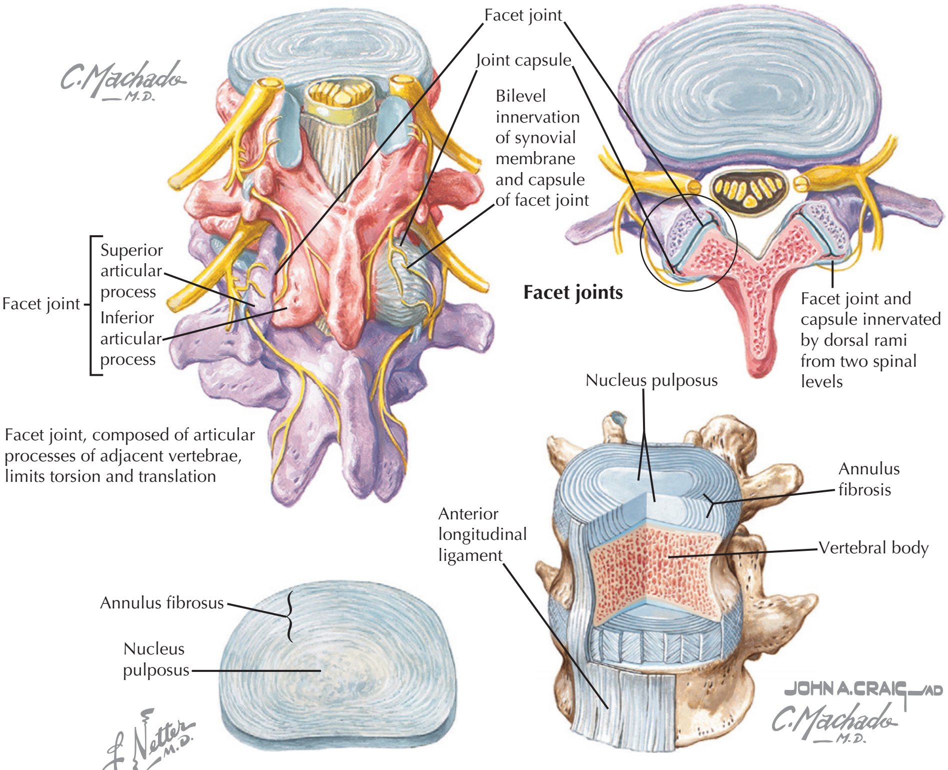

Left lateral view
(partially sectioned in median plane)
Anterior longitudinal ligament
Lumbar vertebral body
Intervertebral disc
Anterior longitudinal ligament
Posterior longitudinal ligament
Inferior articular process
Capsule of zygapophyseal (facet) joint *(partially opened)*
Superior articular process
Transverse process
Spinous process
Ligamentum flavum
Interspinous ligament
Supraspinous ligament
Intervertebral foramen


L1
L5
S1
Conus medullaris
Cauda equina
Intervertebral disc

Lumbar MRI, sagittal view


Pedicle *(cut)*
Intervertebral disc
Posterior longitudinal ligament
Superior articular processes; facet tropism (difference in facet axis) on right side
Spinous process
Lamina
Transverse process
Inferior articular process
Ligamentum flavum
Iliolumbar ligament
Iliac crest
Pedicle
Pars inter-articularis

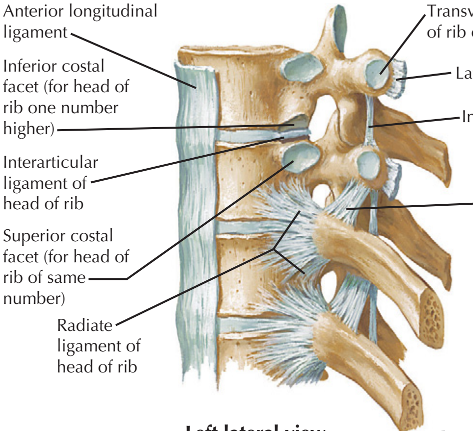
Posterior view


Facet joint
Joint capsule
Bilevel innervation of synovial membrane and capsule of facet joint
Facet joint
Superior articular process
Inferior articular process
Facet joint, composed of articular processes of adjacent vertebrae, limits torsion and translation
Facet joint and capsule innervated by dorsal rami from two spinal levels
Nucleus pulposus
Annulus fibrosis
Vertebral body
Anterior longitudinal ligament
Annulus fibrosus
Nucleus pulposus
C. Machado M.D.
F. Netter M.D.
JOHN A. CRAIG AD

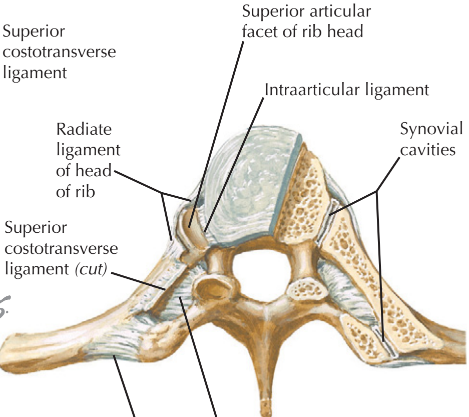
Facet joints

Intervertebral disc

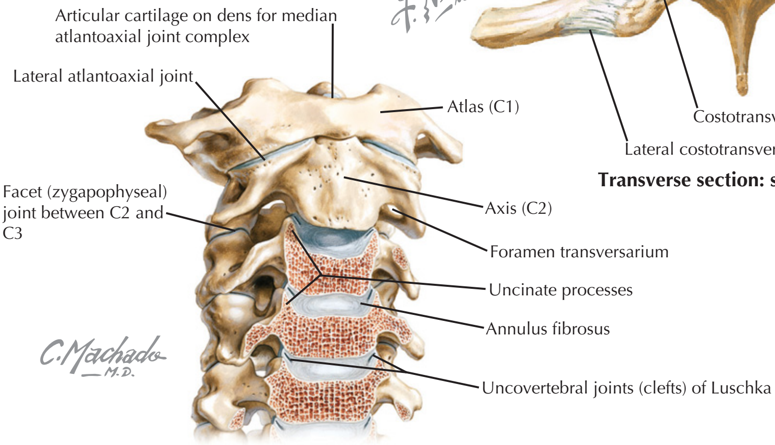
LIGAMENT	ATTACHMENTS	COMMENTS
FACET ([ZYG]APOPHYSEAL) JOINT		
Paired (L & R) articulations between the inferior & superior articular processes of adjacent vertebrae. • Orientation changes from semi-coronal (cervical) to sagittal (lumbar) and allows/dictates motion of that segment. • Inferior articular process is anterior & inferior (C-spine) and anterior & lateral (L-spine) to the superior articular process. • Joint innervation is from dorsal rami of two adjacent nerve root levels. • Hypertrophic changes in degenerative disease can cause/contribute to nerve root impingement.		
Capsule	Surrounds the articular processes	Weak structure, adds little support. May hypertrophy in degenerative joints and narrow neural foramen.
Meniscus/disc	Within joint b/w processes	Can be injured or degenerate and be source of pain
INTERVERTEBRAL DISCS		
Stabilize and maintain spine by anchoring adjacent vertebral bodies. Allow flexibility and absorb/distribute energy. • The discs make up 25% of the spine height. Disc degeneration with age results in loss of spinal column height.		
Annulus fibrosus	Strong attachments to end plates of adjacent vertebral bodies (via "outer annulus")	• Two layers: 1. outer annulus: dense fibers (type 1 collagen); 2. inner annulus: fibrocartilage, looser type 2 collagen fibers • Fibers are obliquely oriented and resist tensile loads • Outer layer innervated, tears can cause back pain (esp. LBP)
Nucleus pulposus	Contained within the annulus	• Gelatinous mass of water, proteoglycans, & type 2 collagen • Resists compressive loads (highest when sitting forward) • Water & proteoglycan content decrease with advancing age • Can herniate out of annulus & compress nerve root (L4-5 #1)


Anterior longitudinal ligament
Inferior costal facet (for head of rib one number higher)
Interarticular ligament of head of rib
Superior costal facet (for head of rib of same number)
Radiate ligament of head of rib
Transverse costal facet (for tubercle of rib of same number as vertebra)
Lateral costotransverse ligament
Intertransverse ligament
Superior costotransverse ligament

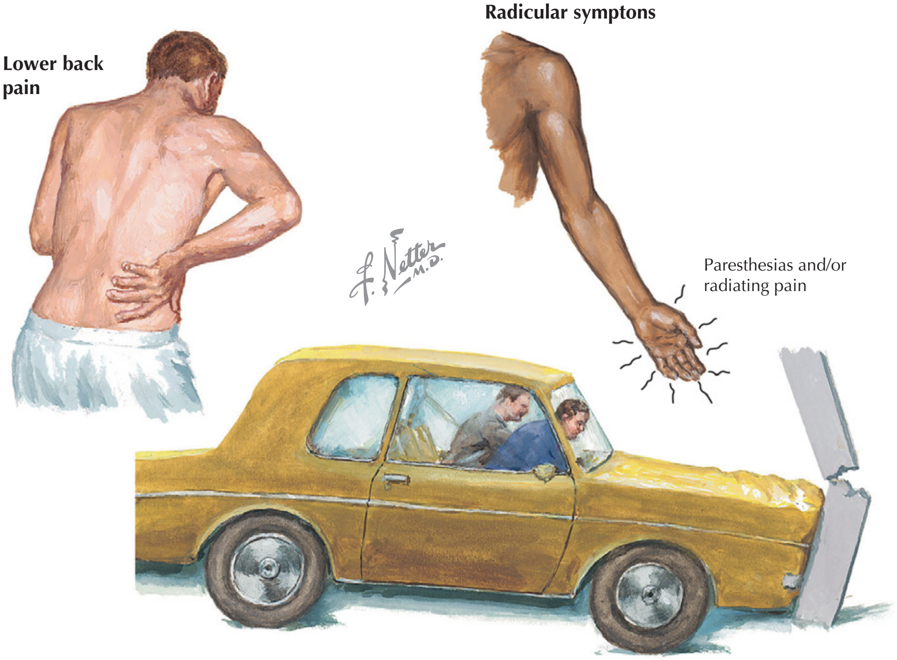
Left lateral view


Superior articular facet of rib head
Intraarticular ligament
Synovial cavities
Radiate ligament of head of rib
Superior costotransverse ligament (cut)
Costotransverse ligament
Lateral costotransverse ligament

Transverse section: superior view

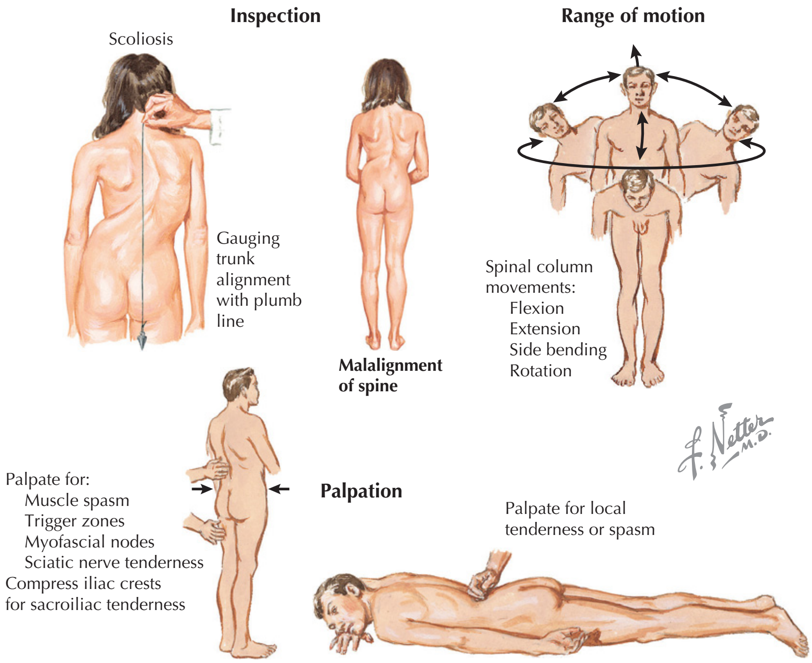

Articular cartilage on dens for median atlantoaxial joint complex
Lateral atlantoaxial joint
Atlas (C1)
Facet (zygapophyseal) joint between C2 and C3
Axis (C2)
Foramen transversarium
Uncinate processes
Annulus fibrosus
Uncovertebral joints (clefts) of Luschka

LIGAMENT	ATTACHMENTS	COMMENTS
UNCOVERTEBRAL JOINTS		
• "Joints of Luschka": articulation in cervical spine b/w the uncinate process on the concave superior end plates of the inferior vertebral body & the articulating portion of the convex inferior end plate of the superior adjacent vertebral body. • Articular cartilage at this joint can degenerate and contribute to cervical spondylosis.		
COSTOVERTEBRAL JOINTS		
Articulation between the head of the rib and the thoracic vertebra (body and transverse process)		
Capsule	Surround head of rib/joint	Weak support of joint
Intraarticular	Head of rib to body/disc	Deep to radiate
Radiate	Head of rib to bodies & disc	Fan shaped, reinforces joint anteriorly
Costotransverse	Transverse process to rib	Superior costotransverse attaches to TP of superior vertebrae
OTHER		
Neural foramen: Boundaries: *superior & inferior:* pedicles; *anterior:* body & disc (uncinate process in C-spine); *posterior:* facet joint & capsule. Osteophytes, discs, facet hypertrophy, and ligamentum flavum can all narow foramen.		

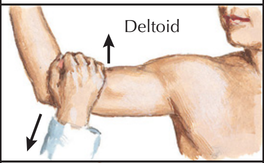
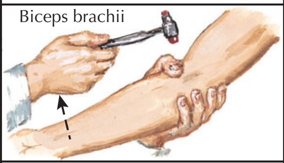
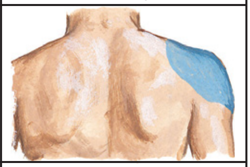
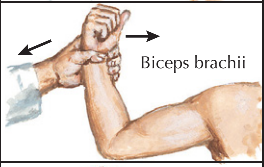
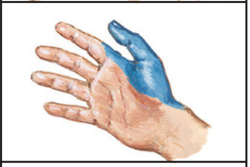
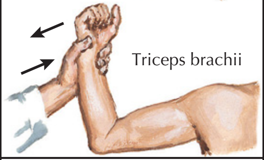
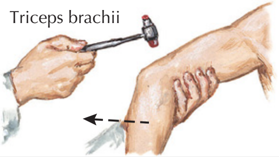
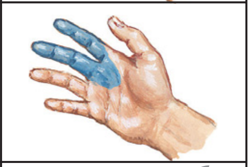
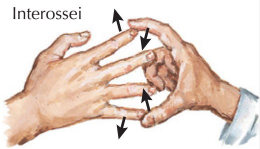
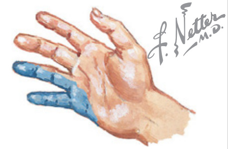


Head-on collision with stationary object or oncoming vehicle may, if seat belts not used, drive forehead against windshield. This sharply hyperextends neck, resulting in dislocation with or without fracture of cervical vertebrae

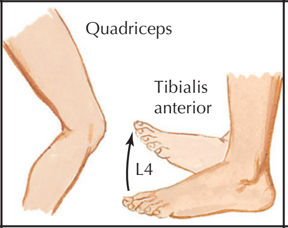
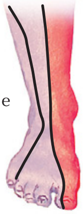
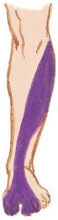
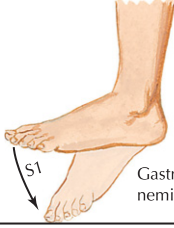
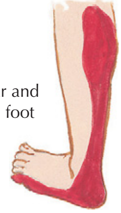
QUESTION	ANSWER	CLINICAL APPLICATION
1. Age	Young	Disc injuries, spondylolisthesis
	Middle age	Sprain/strain, nucleus pulposis/disc (HNP), degenerative disc disease (DDD)
	Elderly	Spinal stenosis, herniated disc, DDD, spondylosis
2. Pain		
a. Character	Radiating (shooting)	Radiculopathy (herniated nucleus pulposis [HNP])
	Diffuse, dull, non radiating	Cervical or lumbar strain
b. Location	Unilateral vs bilateral	Unilateral: herniated nucleus pulposis; Bilateral: systemic or metabolic disease, space-occupying lesion
	Neck	Cervical spondylosis, neck sprain or muscle strain
	Arms (+/– radiating)	Cervical spondylosis (+/– myelopathy), HNP
	Lower back	DDD, back sprain/muscle strain, spondylolisthesis
	Legs (+/– radiating)	Herniated nucleus pulposis, spinal stenosis
c. Occurrence	Night pain	Infection, tumor
	With activity	Usually mechanical etiology
d. Alleviating	Arms elevated	Herniated cervical disc (HNP)
	Sit down	Spinal stenosis (stenosis relieved)
e. Exacerbating	Back extension	Spinal stenosis (going down stairs), DJD/facet hypertrophy
3. Trauma	MVA (seatbelt?)	Cervical strain (whiplash), cervical fractures, ligamentous injury
4. Activity	Sports (stretching injury)	“Burners/stingers”(esp. in football), fractures
5. Neurologic symptoms	Pain, numbness, tingling	Radiculopathy, neuropathy, cauda equina syndrome
	Spasticity, clumsiness	Myelopathy
	Bowel/bladder symptoms	Cauda equina syndrome
6. Systemic complaints	Fever, weight loss, night sweats	Infection, tumor


Inspection
Scoliosis
Gauging trunk alignment with plumb line
Malalignment of spine
Range of motion
Spinal column movements:
Flexion
Extension
Side bending
Rotation
F. Netter M.D.
Palpation
Palpate for:
Muscle spasm
Trigger zones
Myofascial nodes
Sciatic nerve tenderness
Compress iliac crests for sacroiliac tenderness
Palpate for local tenderness or spasm

EXAM	TECHNIQUE	CLINICAL APPLICATION
INSPECTION		
Gait	Leaning forward Wide-based	Spinal stenosis Myelopathy
Alignment	Malalignment	Dislocation, scoliosis, lordosis, kyphosis
Posture	Head tilted Pelvis tilted	Dislocation, spasm, spondylosis, torticollis Loss of lordosis: spasm
Skin	Disrobe patient	Cafe-au-lait spots, growths: possibly neurofibromatosis Port wine spots, soft masses: possibly spina bifida
PALPATION		
Bony structures	Spinous processes	Focal/point tenderness: fracture; step-off: dislocation/ spondylolisthesis
Soft tissues	Cervical facet joints Coccyx, via rectal exam Paraspinal muscles	Tenderness: osteoarthritis, dislocation Tenderness: fracture or contusion Diffuse tenderness: sprain/muscle strain; trigger point: spasm
RANGE OF MOTION		
Flexion/extension: cervical Flexion/extension: lumbar	Chin to chest/occiput back Touch toes with legs straight	Normal: Flexion: chin within 3-4cm of chest; ext. 70° Normal: 45-60° in flexion, 20-30° in extension
Lateral flexion: cervical Lateral flexion: lumbar	Ear to shoulder Bend to each side	Normal: 30-40° in each direction Normal: 10-20° in each direction
Rotation: cervical Rotation: lumbar	Stabilize shoulders: rotate Stabilize hip: rotate	Normal: 75° in each direction Normal: 5-15° in each direction

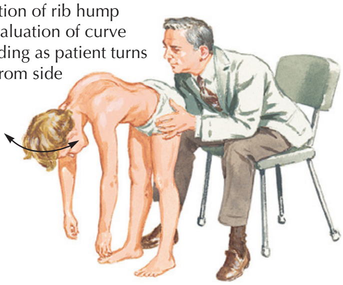
Level	Motor	Reflex	Sensory
C5	 Deltoid	 Biceps brachii	
C6	 Biceps brachii	Brachioradialis	
C7	 Triceps brachii	 Triceps brachii	
C8	 Interossei	None	

EXAM	TECHNIQUE	CLINICAL APPLICATION
NEUROVASCULAR		
Cervical		
Sensory		
C5	Lateral shoulder	Deficit indicates a corresponding cervical root compression/lesion
C6	Thumb	Deficit indicates a corresponding cervical root compression/lesion
C7	Middle finger	Deficit indicates a corresponding cervical root compression/lesion
C8	Ring & small fingers	Deficit indicates a corresponding cervical root compression/lesion
T1	Ulnar forearm & hand	Deficit indicates a corresponding cervical root compression/lesion
Motor		
C5	Deltoid: resisted abduction	Weakness indicates corresponding cervical root compression/lesion
C6	Biceps: resisted elbow flexion	Weakness indicates corresponding cervical root compression/lesion
C7	Triceps: resisted elbow ext.	Weakness indicates corresponding cervical root compression/lesion
C8	Intrinsics: resisted finger abduction	Weakness indicates corresponding cervical root compression/lesion
T1		Weakness indicates corresponding cervical root compression/lesion
Reflexes		
C5	Biceps	Hypoactive/absent indicates C5 radiculopathy
C6	Brachioradialis (BR)	Hypoactive/absent indicates C6 radiculopathy
C7	Triceps	Hypoactive/absent indicates C7 radiculopathy
Inverted radial	Tap BR tendon in distal forearm	Hypoactive brachioradialis & hyperactive finger flexion: myelopathy
Hoffman's	Flick MF DIPJ into flexion	Pathologic if thumb IPJ flexes: myelopathy
Pulses		
	Brachial, radial, ulnar	Diminished/absent = vascular injury or compromise

Level	Motor	Reflex	Sensory
L4	 Quadriceps Tibialis anterior 	Patella tendon ("knee jerk")	 Medial calf/ankle
L5	Extensor hallucis longus	None	 Dorsal foot and 1st web space
S1	 Gastroc-nemius 	Achilles tendon ("ankle jerk")	 Plantar and lateral foot

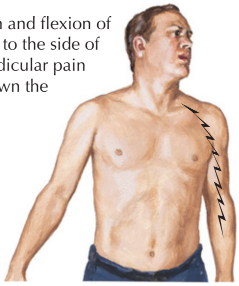
EXAM	TECHNIQUE	CLINICAL APPLICATION
NEUROVASCULAR		
Lumbar		
Sensory		
L3	Anterior & medial thigh	Deficit indicates corresponding lumbar root compression/lesion
L4	Medial leg & ankle	Deficit indicates corresponding lumbar root compression/lesion
L5	Dorsal foot & 1st web space	Deficit indicates corresponding lumbar root compression/lesion
S1	Lateral & plantar foot	Deficit indicates corresponding lumbar root compression/lesion
S2-4	Perianal sensation	Deficit indicates corresponding lumbar root compression/lesion
Motor		
L3-4	Quadriceps: knee extension	Weakness indicates corresponding lumbar root compression/lesion
L4	Tibialis anterior: ankle DF	Weakness indicates corresponding lumbar root compression/lesion
L5	Extensor hallucis longus: toe DF	Weakness indicates corresponding lumbar root compression/lesion
S1	Gastrocnemius: ankle PF	Weakness indicates corresponding lumbar root compression/lesion
S2-4	Anal sphincter: anal squeeze	Weakness indicates corresponding lumbar root compression/lesion
Reflexes		
L4	Patellar tendon ("knee jerk")	Hypoactive/absent indicates L4 radiculopathy
S1	Achilles tendon ("ankle jerk")	Hypoactive/absent indicates S1 radiculopathy
S2-3	Bulbocavernosus	Hypoactive/absent indicates S2-3 radiculopathy or spinal shock
Babinski	Run stick along plantar foot	Upgoing great toe: upper motor neuron/myelopathy
Ankle clonus	Rapidly flex & extend ankle	Multiple beats of clonus: upper motor neuron/myelopathy
Pulses		
	Posterior tibial, dorsalis pedis	Diminished/absent = vascular injury or compromise

Forward bending test



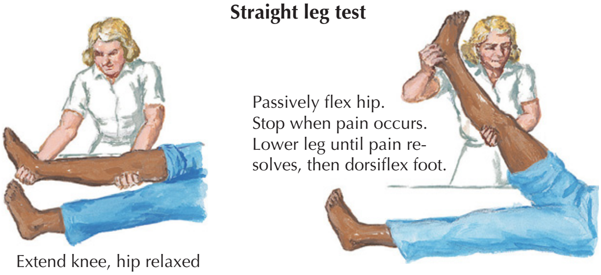
Estimation of rib hump and evaluation of curve unwinding as patient turns trunk from side to side

Spurling maneuver



Hyperextension and flexion of neck ipsilateral to the side of lesion cause radicular pain in neck and down the affected arm

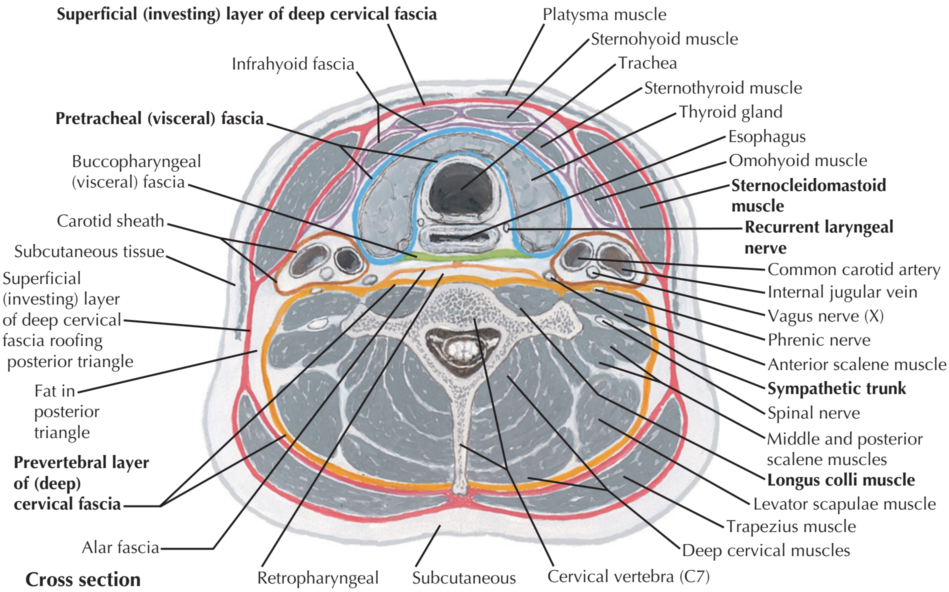
Straight leg test



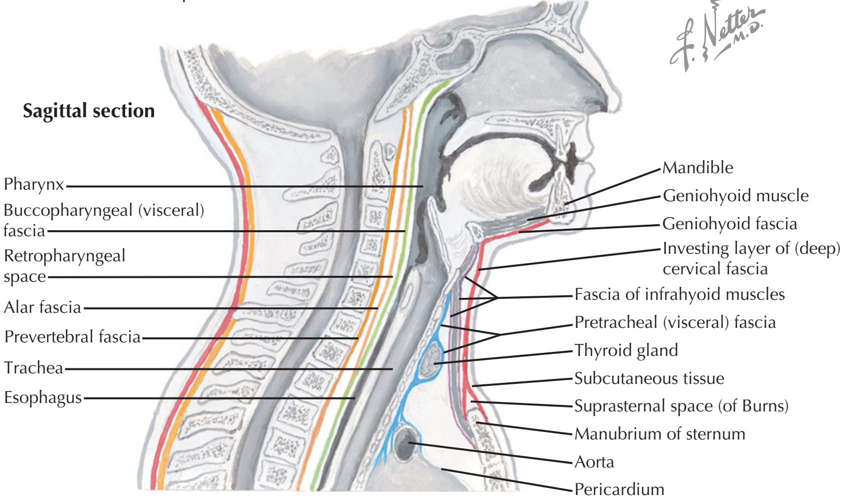
Extend knee, hip relaxed

Passively flex hip. Stop when pain occurs. Lower leg until pain resolves, then dorsiflex foot.

EXAM	TECHNIQUE	CLINICAL APPLICATION
	SPECIAL TESTS	
	Cervical	
Spurling	Axial load, then laterally flex & rotate neck	Radiating pain indicates nerve root compression
Distraction	Upward distracting force	Relief of symptoms indicates foraminal compression of nerve root
Kernig	Supine: flex neck	Pain in or radiating to legs indicates meningeal irritation/ infection
Brudzinski	Supine: flex neck, hip flex	Pain reduction with knee flexion indicates meningeal irritation
	Lumbar	
Straight leg	Flex hip to pain, dorsiflex foot	Symptoms reproduced (pain radiating below knee) indicative of radiculopathy
Straight leg 90/90	Supine: flex hip & knee 90°, extend knee	>20° of flexion = tight hamstrings: source of pain
Bowstring	Raise leg, flex knee, popliteal press	Radicular pain with popliteal pressure indicates sciatic nerve cause
Sitting root (flip sign)	Seated: distract patient, passively extend knee	Patient with sciatic pain will arch/flip backward when knee extended
Forward bending	Standing, bend at waist	Asymmetry of back (scapula/ribs) is indicative of scoliosis
Hoover	Supine: hands under heels, patient then raises one leg	Pressure should be felt under opposite heel. No pressure indicates lack of effort, not true weakness
Waddell signs	Presence indicates nonorganic pathology: 1. Exaggerated response/overreaction, 2. Pain to light touch, 3. Nonanatomic pain localization, 4. Negative flip sign with positive straight leg test	

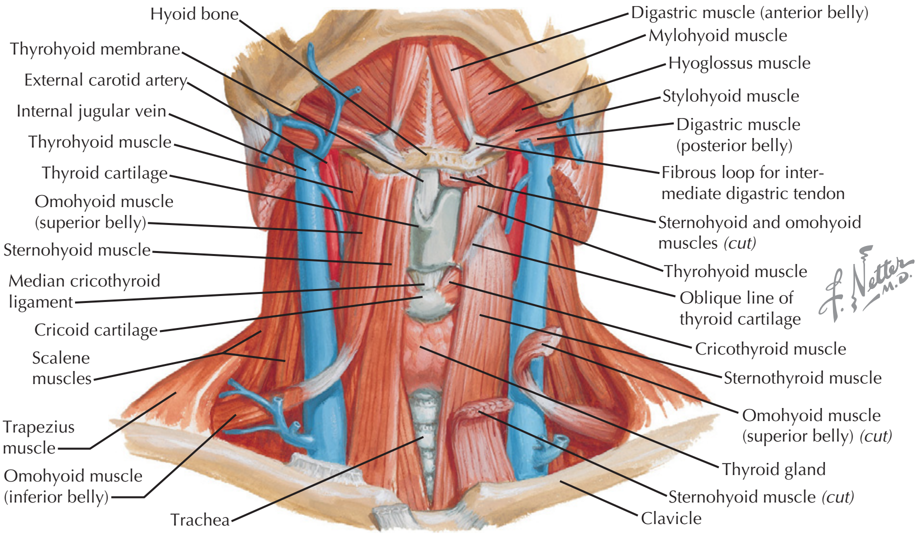

Superficial (investing) layer of deep cervical fascia
Infrahyoid fascia
Pretracheal (visceral) fascia
Buccopharyngeal (visceral) fascia
Carotid sheath
Subcutaneous tissue
Superficial (investing) layer of deep cervical fascia roofing posterior triangle
Fat in posterior triangle
Prevertebral layer of (deep) cervical fascia
Alar fascia
Retropharyngeal space
Subcutaneous tissue
Cervical vertebra (C7)
Platysma muscle
Sternohyoid muscle
Trachea
Sternothyroid muscle
Thyroid gland
Esophagus
Omohyoid muscle
Sternocleidomastoid muscle
Recurrent laryngeal nerve
Common carotid artery
Internal jugular vein
Vagus nerve (X)
Phrenic nerve
Anterior scalene muscle
Sympathetic trunk
Spinal nerve
Middle and posterior scalene muscles
Longus colli muscle
Levator scapulae muscle
Trapezius muscle
Deep cervical muscles

Cross section


Pharynx
Buccopharyngeal (visceral) fascia
Retropharyngeal space
Alar fascia
Prevertebral fascia
Trachea
Esophagus
Mandible
Geniohyoid muscle
Geniohyoid fascia
Investing layer of (deep) cervical fascia
Fascia of infrahyoid muscles
Pretracheal (visceral) fascia
Thyroid gland
Subcutaneous tissue
Suprasternal space (of Burns)
Manubrium of sternum
Aorta
Pericardium

Sagittal section

LAYER	CONTENTS	COMMENT
FASCIA LAYERS		
Platysma	Thin superficial muscle	Highly vascular, must be split to access cervical spine
Deep cervical fascia	Invests sternocleidomastoid	Incised in anterior cervical approach
Pretracheal fascia	Invests thyroid, trachea	Incised off of carotid sheath to access cervical spine
Carotid sheath	Carotid artery, internal jugular vein, vagus nerve (CN 10)	Left intact and used to retract structures laterally unless access to contents of sheath is needed
Prevertebral fascia	Covers A.L.L. & longus colli	Deepest fascial layer, incised to access vertebral body and disc


Hyoid bone
Thyrohyoid membrane
External carotid artery
Internal jugular vein
Thyrohyoid muscle
Thyroid cartilage
Omohyoid muscle (superior belly)
Sternohyoid muscle
Median cricothyroid ligament
Cricoid cartilage
Scalene muscles
Trapezius muscle
Omohyoid muscle (inferior belly)
Trachea
Digastric muscle (anterior belly)
Mylohyoid muscle
Hyoglossus muscle
Stylohyoid muscle
Digastric muscle (posterior belly)
Fibrous loop for intermediate digastric tendon
Sternohyoid and omohyoid muscles *(cut)*
Thyrohyoid muscle
Oblique line of thyroid cartilage
Cricothyroid muscle
Sternothyroid muscle
Omohyoid muscle (superior belly) *(cut)*
Thyroid gland
Sternohyoid muscle *(cut)*
Clavicle
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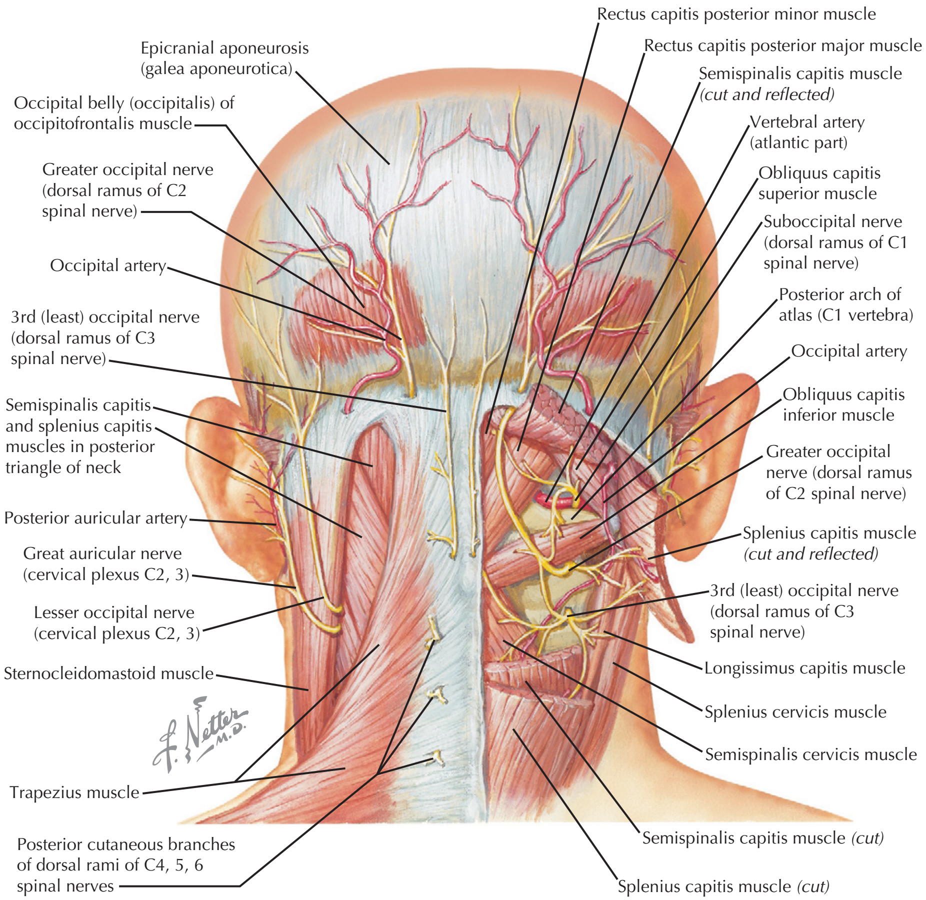
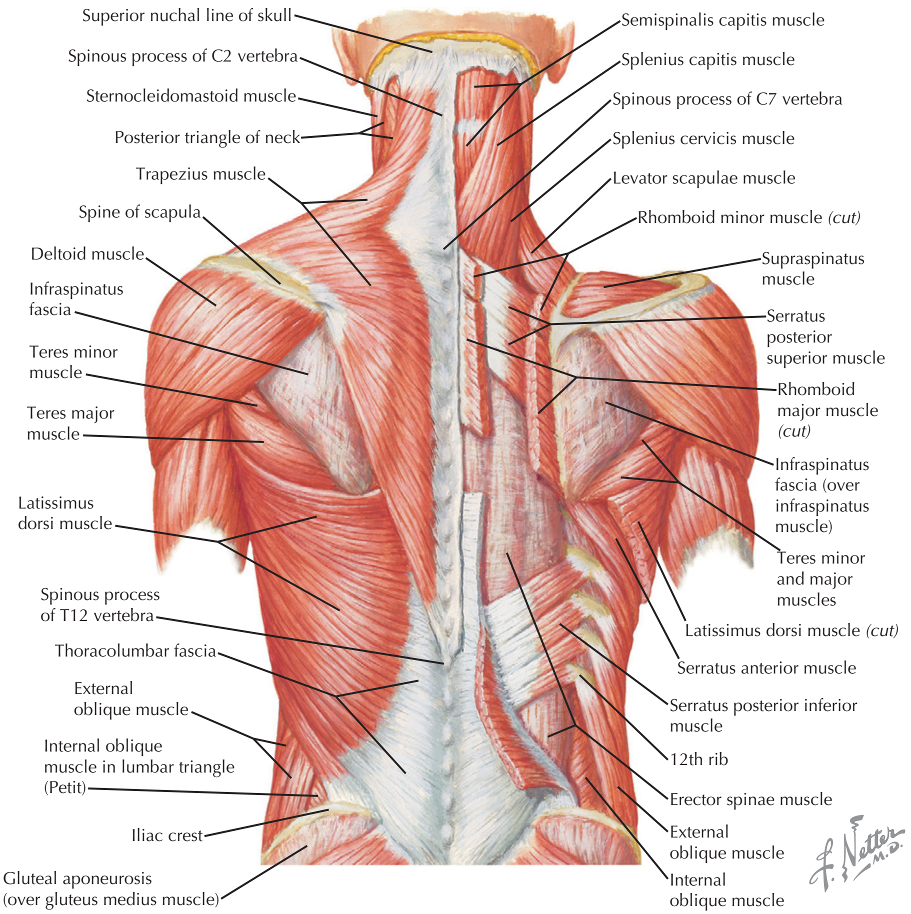
MUSCLE	ORIGIN	INSERTION	ACTION	NERVE
ANTERIOR NECK				
Platysma	Fascia: deltoid/pectoralis major	Mandible; skin	Depress jaw	CN 7
Sternocleidomastoid	Manubrium & clavicle	Mastoid process	Turn head opposite side	CN 11
ANTERIOR CERVICAL TRIANGLE				
Suprahyoid Muscles				
Digastric	Anterior: mandible Posterior: mastoid notch	Hyoid body	Elevate hyoid, depress mandible	Anterior: mylohyoid (CN 5) Post: facial (CN 7)
Mylohyoid	Mandible	Raphe on hyoid	Same as above	Mylohyoid (CN 5)
Stylohyoid	Styloid process	Body of hyoid	Elevate hyoid	Facial nerve (CN 7)
Geniohyoid	Genial tubercle of mandible	Body of hyoid	Elevate hyoid	C1 via CN 12
Infrahyoid Muscles				
Superficial				
Sternohyoid	Manubrium & clavicle	Body of hyoid	Depress hyoid	Ansa cervicalis
Omohyoid	Suprascapular notch	Body of hyoid	Depress hyoid	Ansa cervicalis
Deep				
Thyrohyoid	Thyroid cartilage	Greater horn of hyoid	Depress hyoid/larynx	C1 via CN 12
Sternothyroid	Manubrium	Thyroid cartilage	Depress/retract hyoid/larynx	Ansa cervicalis (C1-3)


Epicranial aponeurosis (galea aponeurotica)
Occipital belly (occipitalis) of occipitofrontalis muscle
Greater occipital nerve (dorsal ramus of C2 spinal nerve)
Occipital artery
3rd (least) occipital nerve (dorsal ramus of C3 spinal nerve)
Semispinalis capitis and splenius capitis muscles in posterior triangle of neck
Posterior auricular artery
Great auricular nerve (cervical plexus C2, 3)
Lesser occipital nerve (cervical plexus C2, 3)
Sternocleidomastoid muscle
Trapezius muscle
Posterior cutaneous branches of dorsal rami of C4, 5, 6 spinal nerves
Rectus capitis posterior minor muscle
Rectus capitis posterior major muscle
Semispinalis capitis muscle *(cut and reflected)*
Vertebral artery (atlantic part)
Obliquus capitis superior muscle
Suboccipital nerve (dorsal ramus of C1 spinal nerve)
Posterior arch of atlas (C1 vertebra)
Occipital artery
Obliquus capitis inferior muscle
Greater occipital nerve (dorsal ramus of C2 spinal nerve)
Splenius capitis muscle *(cut and reflected)*
3rd (least) occipital nerve (dorsal ramus of C3 spinal nerve)
Longissimus capitis muscle
Splenius cervicis muscle
Semispinalis cervicis muscle
Semispinalis capitis muscle *(cut)*
Splenius capitis muscle *(cut)*

MUSCLE	ORIGIN	INSERTION	ACTION	NERVE
POSTERIOR NECK				
Scalene muscles				
Anterior	C3-6 transverse process	1st rib	Laterally flexes neck and elevates 1st or 2nd rib	C5-C8 nerve roots
Middle	C2-7 transverse process	1st rib		
Posterior	C4-6 transverse process	2nd rib		
Suboccipital Triangle				
Rectus capitis posterior major	Spine of axis	Inferior nuchal line	Extend, rotate, laterally flex head	Suboccipital nerve
Rectus capitis posterior minor	Posterior tubercle of atlas	Occipital bone	Extend, laterally flex	Suboccipital nerve
Obliquus capitis superior	Atlas transverse process	Occipital bone	Extend, rotate, laterally flex	Suboccipital nerve
Obliquus capitis inferior	Spine of axis	Atlas transverse process	Extend, laterally rotate	Suboccipital nerve
Semispinalis, see page 58; Splenius, see page 57.				


Superior nuchal line of skull
Spinous process of C2 vertebra
Sternocleidomastoid muscle
Posterior triangle of neck
Trapezius muscle
Spine of scapula
Deltoid muscle
Infraspinatus fascia
Teres minor muscle
Teres major muscle
Latissimus dorsi muscle
Spinous process of T12 vertebra
Thoracolumbar fascia
External oblique muscle
Internal oblique muscle in lumbar triangle (Petit)
Iliac crest
Gluteal aponeurosis (over gluteus medius muscle)
Semispinalis capitis muscle
Splenius capitis muscle
Spinous process of C7 vertebra
Splenius cervicis muscle
Levator scapulae muscle
Rhomboid minor muscle *(cut)*
Supraspinatus muscle
Serratus posterior superior muscle
Rhomboid major muscle *(cut)*
Infraspinatus fascia (over infraspinatus muscle)
Teres minor and major muscles
Latissimus dorsi muscle *(cut)*
Serratus anterior muscle
Serratus posterior inferior muscle
12th rib
Erector spinae muscle
External oblique muscle
Internal oblique muscle
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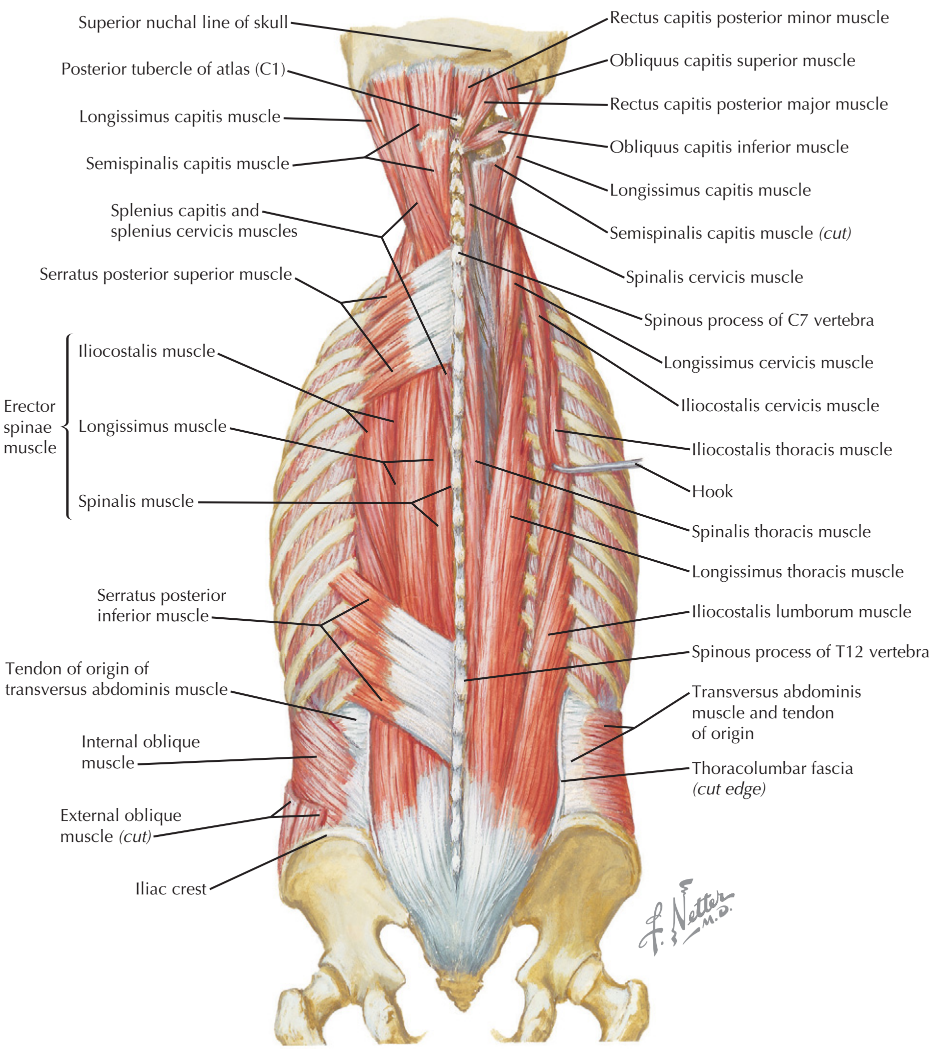
MUSCLE	ORIGIN	INSERTION	ACTION	NERVE
SUPERFICIAL (EXTRINSIC)				
Trapezius	Spinous process C7-T12	Clavicle; scapula (spine, acromion)	Rotate scapula	CN 11
Latissimus dorsi	Spinous process T6-S5	Humerus	Extend, adduct, IR arm	Thoracodorsal
Levator scapulae	Transverse process C1-4	Scapula (medial)	Elevate scapula	Dorsal scapular, C3, C4 (dorsal rami)
Rhomboid minor	Spinous process C7-T1	Scapula (spine)	Adduct scapula	Dorsal scapular
Rhomboid major	Spinous process T2-T5	Scapula (medial border)	Adduct scapula	Dorsal scapular
Serratus posterior superior	Spinous process C7-T3	Ribs 2-5 (upper border)	Elevate ribs	Intercostal n. (T1-4)
Serratus posterior inferior	Spinous process T11-L3	Ribs 9-12 (lower border)	Depress ribs	Intercostal n. (T9-12)


Superior nuchal line of skull
Posterior tubercle of atlas (C1)
Longissimus capitis muscle
Semispinalis capitis muscle
Splenius capitis and splenius cervicis muscles
Serratus posterior superior muscle
Erector spinae muscle
Iliocostalis muscle
Longissimus muscle
Spinalis muscle
Serratus posterior inferior muscle
Tendon of origin of transversus abdominis muscle
Internal oblique muscle
External oblique muscle *(cut)*
Iliac crest
Rectus capitis posterior minor muscle
Obliquus capitis superior muscle
Rectus capitis posterior major muscle
Obliquus capitis inferior muscle
Longissimus capitis muscle
Semispinalis capitis muscle *(cut)*
Spinalis cervicis muscle
Spinous process of C7 vertebra
Longissimus cervicis muscle
Iliocostalis cervicis muscle
Iliocostalis thoracis muscle
Hook
Spinalis thoracis muscle
Longissimus thoracis muscle
Iliocostalis lumborum muscle
Spinous process of T12 vertebra
Transversus abdominis muscle and tendon of origin
Thoracolumbar fascia *(cut edge)*
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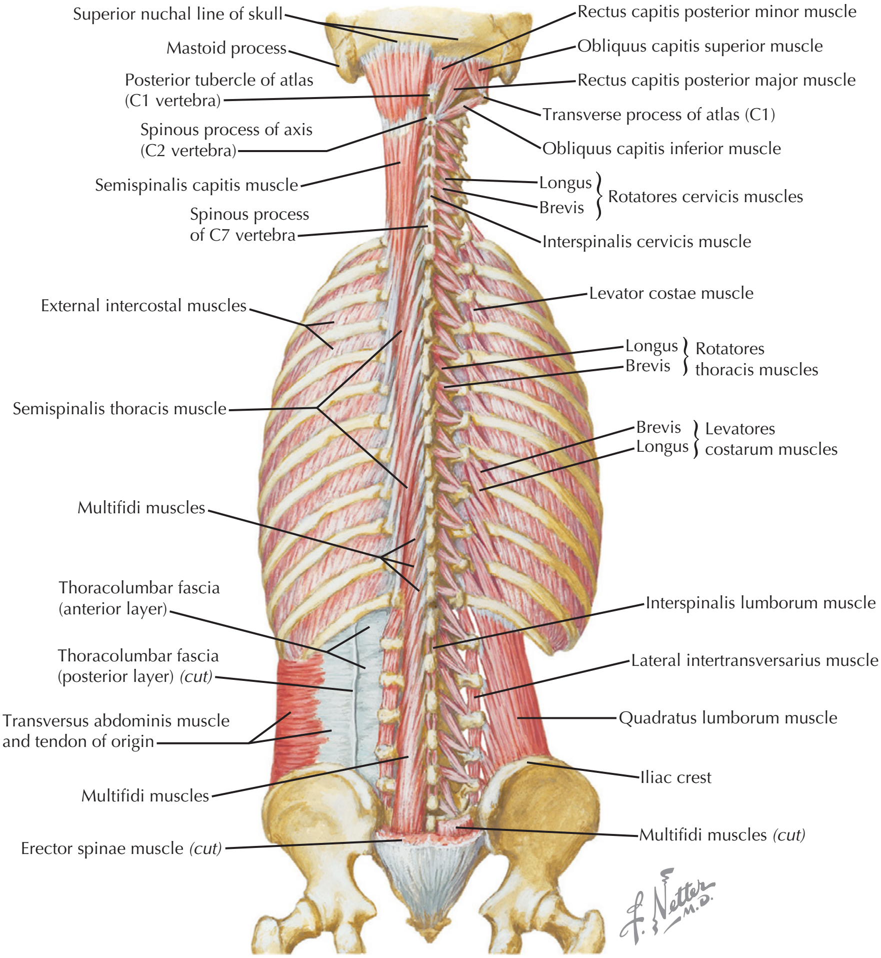
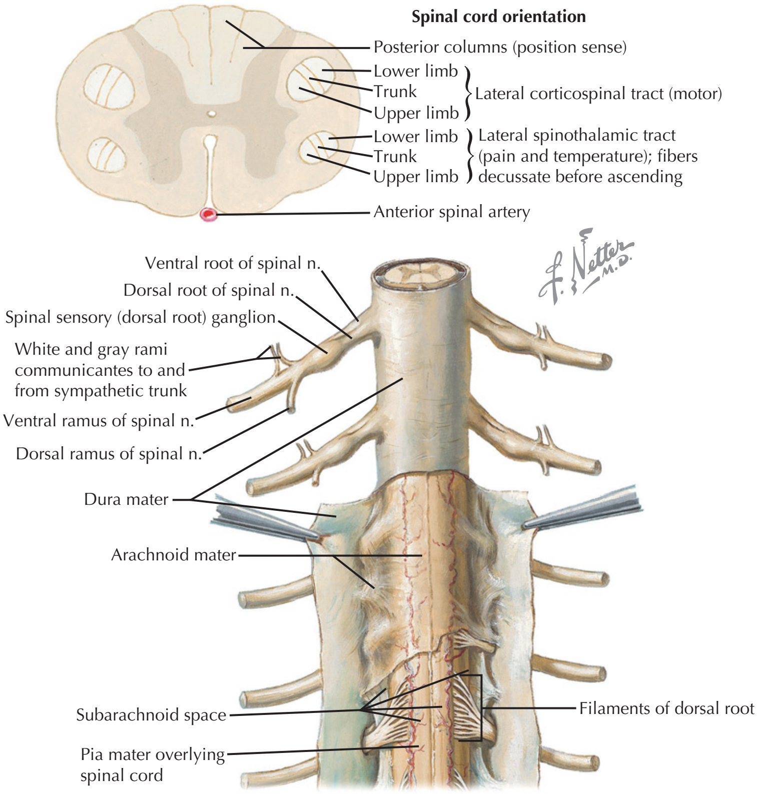
MUSCLE	ORIGIN	INSERTION	ACTION	NERVE
DEEP (INTRINSIC)				
Superficial Layer: Spinotransverse Group				
Splenius capitis Splenius cervicis	Ligamentum nuchae Spinous process T1-6	Mastoid & nuchal line Transverse process C1-4	Both: laterally flex & rotate neck to same side	Dorsal rami of inferior cervical nerves
Intermediate Layer: Sacrospinalis Group (Erector Spinae)				
Iliocostalis Longissimus Spinalis	Common origin: sacrum, iliac crest, and lumbar spinous process	Ribs T & C spinous process, mastoid process T-spine: spinous process	Laterally flex, extend, and rotate head (to same side) and vertebral column	Dorsal rami of spinal nerves
All have three parts: thoracis, cervicis, and capitus				


Superior nuchal line of skull
Mastoid process
Posterior tubercle of atlas (C1 vertebra)
Spinous process of axis (C2 vertebra)
Semispinalis capitis muscle
Spinous process of C7 vertebra
External intercostal muscles
Semispinalis thoracis muscle
Multifidi muscles
Thoracolumbar fascia (anterior layer)
Thoracolumbar fascia (posterior layer) *(cut)*
Transversus abdominis muscle and tendon of origin
Multifidi muscles
Erector spinae muscle *(cut)*
Rectus capitis posterior minor muscle
Obliquus capitis superior muscle
Rectus capitis posterior major muscle
Transverse process of atlas (C1)
Obliquus capitis inferior muscle
Longus
Brevis
Rotatores cervicis muscles
Interspinalis cervicis muscle
Levator costae muscle
Longus
Brevis
Rotatores thoracis muscles
Brevis
Longus
Levatores costarum muscles
Interspinalis lumborum muscle
Lateral intertransversarius muscle
Quadratus lumborum muscle
Iliac crest
Multifidi muscles *(cut)*

MUSCLE	ORIGIN	INSERTION	ACTION	NERVE
DEEP (INTRINSIC)				
Deep Layers: Transversospinalis Group				
Semispinalis capitus	Transverse process T1-6	Nuchal ridge	Extend head	Dorsal primary rami
Semispinalis (C&T)	Transverse process	Spinous process	Extend, rotate opposite side	Dorsal primary rami
Multifidus (C2-S4)	Transverse process	Spinous process	Flex laterally, rotate opposite	Dorsal primary rami
Rotatores	Transverse process	Spinous process +1	Rotate superior vertebrae opposite	Dorsal primary rami
Levator costarum	Transverse process	Brevis: rib −1 Longus: rib −2	Elevate rib during inspiration	Dorsal primary rami
Interspinales	Spinous process	Spinous process +1	Extend column	Dorsal primary rami
Intertransversarii	Tranverse process	Transverse process +1	Laterally flex column	Dorsal primary rami

Cervical Spine Injury: Incomplete Spinal Syndromes


Spinal cord orientation
Posterior columns (position sense)
Lower limb
Trunk
Upper limb
Lateral corticospinal tract (motor)
Lower limb
Trunk
Upper limb
Lateral spinothalamic tract (pain and temperature); fibers decussate before ascending
Anterior spinal artery
Ventral root of spinal n.
Dorsal root of spinal n.
Spinal sensory (dorsal root) ganglion
White and gray rami communicantes to and from sympathetic trunk
Ventral ramus of spinal n.
Dorsal ramus of spinal n.
Dura mater
Arachnoid mater
Subarachnoid space
Pia mater overlying spinal cord
Filaments of dorsal root
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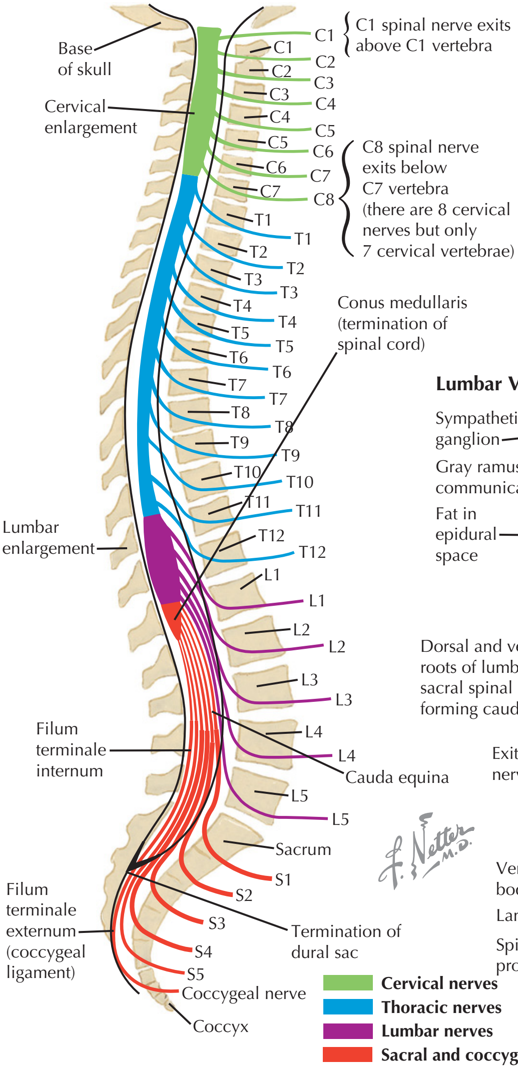
TRACT	FUNCTION	COMMENT
SPINAL CORD		
• Runs from brain stem to conus medullaris (termination at L1) within the spinal canal where it is protected. • Terminale filum and cauda equina (lumbar and sacral nerve roots) continue in the spinal canal. • It has a layered covering (membranes): dura mater, arachnoid mater, pia mater. • It is made up of multiple ascending (sensory) and descending (motor) tracts and columns. • It is wider in the cervical and lumbar spines, where the roots form plexus to innervate the upper and lower extremities. • Paired (R & L) nerve roots emerge from each level. Nerve roots made up of ventral (motor) and dorsal (sensory) roots. • Injury can be either complete or incomplete (see page 42 for spinal cord injuries).		
Descending (Motor)		
Anterior corticospinal	Innervates motor neurons—voluntary motor	Minor motor pathway, injured in anterior cord syndrome
Lateral corticospinal	Innervates motor neurons—voluntary motor	Major motor pathway, injured in Brown-Sequard syndrome
Ascending (Sensory)		
Anterior spinothalamic	Light touch sensation	Injured in anterior cord syndrome
Lateral spinothalamic	Pain and temperature sensation	Injured in Brown-Sequard syndrome
Dorsal columns	Proprioception and vibratory sensation	Usually preserved, injured in posterior cord syndrome


Base of skull
Cervical enlargement
Lumbar enlargement
Filum terminale internum
Filum terminale externum (coccygeal ligament)
C1
C1
C2
C2
C3
C3
C4
C4
C5
C5
C6
C6
C7
C7
C8
T1
T1
T2
T2
T3
T3
T4
T4
T5
T5
T6
T6
T7
T7
T8
T8
T9
T9
T10
T10
T11
T11
T12
T12
L1
L1
L2
L2
L3
L3
L4
L4
L5
L5
Sacrum
S1
S2
S3
S4
S5
Coccygeal nerve
Coccyx
C1 spinal nerve exits above C1 vertebra
C8 spinal nerve exits below C7 vertebra (there are 8 cervical nerves but only 7 cervical vertebrae)
Conus medullaris (termination of spinal cord)
Cauda equina
Termination of dural sac
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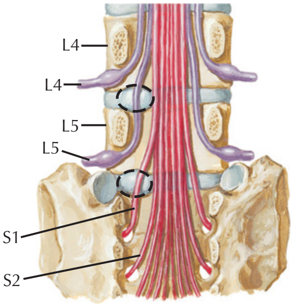
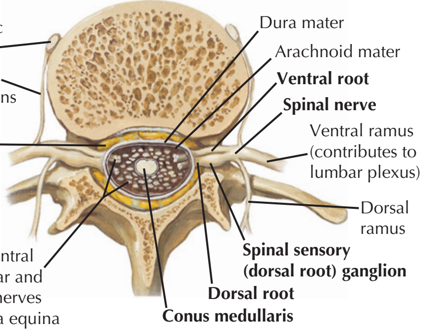
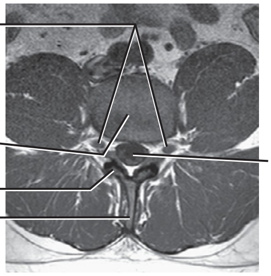
🟩 Cervical nerves
🟦 Thoracic nerves
🟪 Lumbar nerves
🟥 Sacral and coccygeal nerves


L4
L4
L5
L5
S1
S2

Disc protrusion at disc level L4–5 affects L5 spinal nerve, not L4 spinal nerve.

Lumbar Vertebra

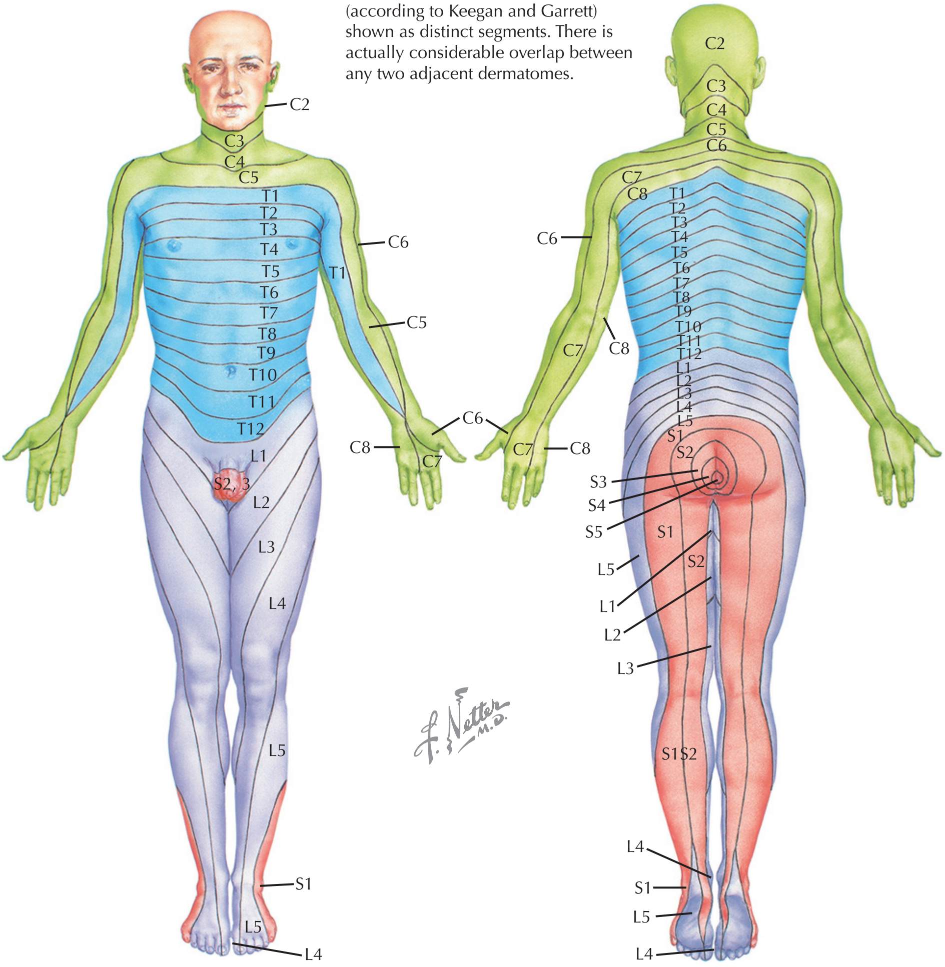

Sympathetic ganglion
Gray ramus communicans
Fat in epidural space
Dorsal and ventral roots of lumbar and sacral spinal nerves forming cauda equina
Dura mater
Arachnoid mater
Ventral root
Spinal nerve
Ventral ramus (contributes to lumbar plexus)
Dorsal ramus
Spinal sensory (dorsal root) ganglion
Dorsal root
Conus medullaris


Exiting spinal nerve roots
Vertebral body
Lamina
Spinous process
Terminal spinal cord and cauda equina within thecal sac

MRI lumbar spine, axial

SPINAL NERVES

- Spinal nerves are made up of a ventral (motor) root and a dorsal (sensory) root. There are 31 pairs (L & R).
- Cell bodies for sensory nerves are in dorsal root ganglia. Motor nerve cell bodies are in ventral horn of spinal cord.
- Roots exit spinal column via the intervertebral (neural) foramen (under pedicle); (C1-7 exit above their vertebrae, C8-L5 exit below their vertebrae [C7 exits above and C8 exits below C7 vertebra]).
- They can be compressed by herniated discs, osteophytes, and hypertrophied soft tissues (ligamentum flavum, facet capsule). In lumbar spine the traversing nerve is usually affected, and exiting root is not (except in far lateral compression).
- The lumbar and sacral nerves form the cauda equina ("horse's tail") in the spinal canal before exiting.
- Spinal nerve divides into dorsal and ventral rami. Dorsal rami innervate local structures (neck and back musculature, overlying skin, facet capsules, etc). Ventral rami contribute to plexus (e.g., cervical, brachial, lumbosacral) and become peripheral nerves to the extremities.
- Ventral rami of spinal nerve commonly referred to as a spinal "roots." The roots combine to form the various plexus.


C2
C3
C4
C5
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
C6
T1
C5
C6
C8
C7
L1
S2, 3
L2
L3
L4
L5
S1
L5
L4
C2
C3
C4
C5
C6
C7
C8
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
S1
S2
C6
C7
C8
C6
C7
C8
S3
S4
S5
S1
S2
L5
L1
L2
L3
S1 S2
L4
S1
L5
L4
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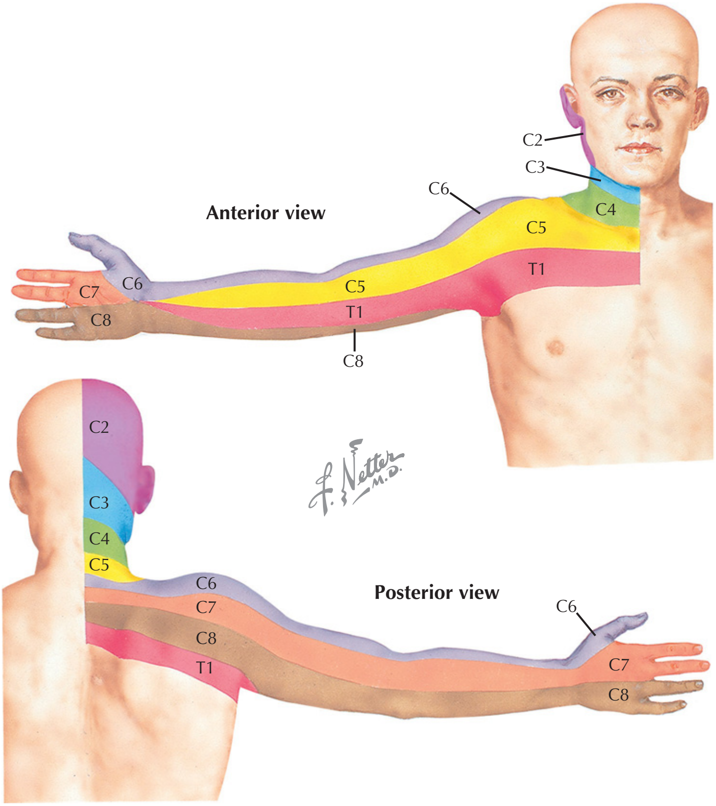
Schematic demarcation of dermatomes (according to Keegan and Garrett) shown as distinct segments. There is actually considerable overlap between any two adjacent dermatomes.

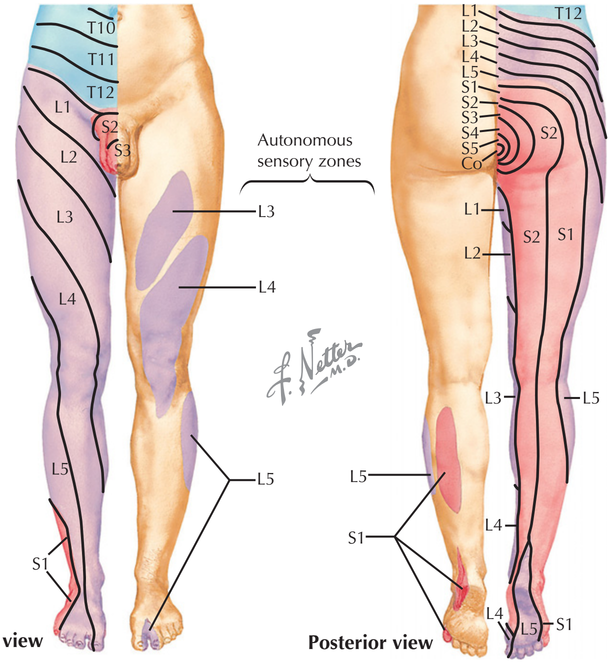
Levels of principal dermatomes

C5	Clavicles
C5, 6, 7	Lateral parts of upper limbs
C8, T1	Medial sides of upper limbs
C6	Thumb
C6, 7, 8	Hand
C8	Ring and little fingers
T4	Level of nipples
T10	Level of umbilicus
L1	Inguinal or groin regions
L1, 2, 3, 4	Anterior and inner surfaces of lower limbs
L4, 5, S1	Foot
L4	Medial side of great toe
S1, 2, L5	Posterior and outer surfaces of lower limbs
S1	Lateral margin of foot and little toe
S2, 3, 4	Perineum



LEVEL	MOTOR	SENSORY	REFLEX	COMMENT
CERVICAL ROOTS				
C1	Geniohyoid Thyrohyoid Rectus capitus	None	None	Part of cervical plexus, contributes to ansa cervicalis
C2	Longus colli/capitis	Parietal scalp	None	Muscle innervation via the dorsal rami
C3	Diaphragm	Occipital scalp	None	Contributes to phrenic & dorsal scapular nerves
C4	Diaphragm	Base of neck	None	Branches to phrenic and dorsal scapular nerves & levator scapula muscle
C5	Deltoid	Lateral shoulder and arm	Biceps	Dorsal scapular n. branches from C5 root
C6	Biceps brachii ECRL, ECRB	Lateral forearm and thumb	Brachioradialis	Most commonly compressed cervical nerve root
C7	Triceps brachii FCR, FCU	Posterior forearm, central hand, and middle finger	Triceps	Exits above C7 vertebra
C8	FDS, FDP	Medial forearm, ulnar fingers	None	Exits below C7 vertebra
T1	Interosseous	Medial arm	None	Only thoracic root in brachial plexus

Schematic demarcation of dermatomes (according to Keegan and Garrett) shown as distinct segments. There is actually considerable overlap between any two adjacent dermatomes.


T10
T11
T12
L1
S2
S3
L2
L3
L4
L5
S1
Autonomous sensory zones
L3
L4
L5
Anterior view
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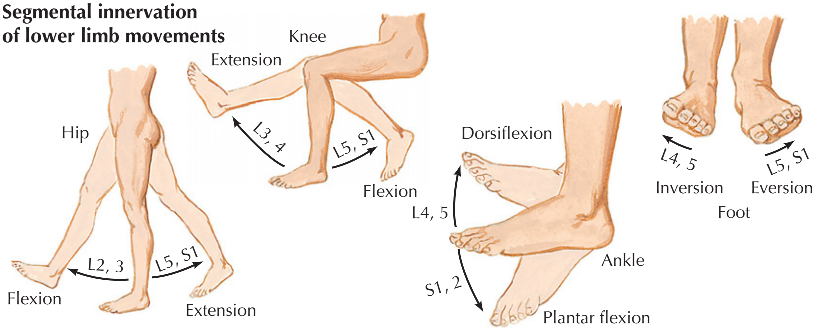
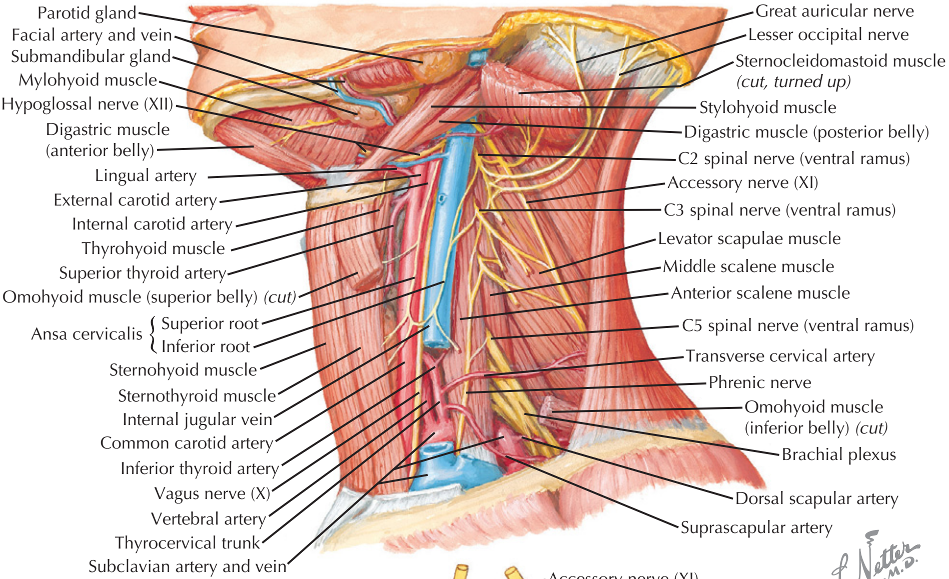
L1
L2
L3
L4
L5
S1
S2
S3
S4
S5
Co
T12
S2
L1
L2
S2
S1
L3
L5
L5
S1
L4
L4
L5
S1
Posterior view


Segmental innervation of lower limb movements
Knee
Extension
L3, 4
L5, S1
Flexion
Hip
L2, 3
L5, S1
Flexion
Extension
Dorsiflexion
L4, 5
S1, 2
Ankle
Plantar flexion
L4, 5
L5, S1
Inversion
Eversion
Foot

LEVEL	MOTOR	SENSORY	REFLEX	COMMENT
LUMBOSACRAL ROOTS				
L1	Transversus abdominis Internal oblique	Inguinal region	None	Rarely injured nerve root
L2	Psoas	Upper thigh	None	Test with hip flexion
L3	Quadriceps	Anterior and medial thigh	None	L3 & L4 tested with quadriceps
L4	Tibialis anterior	Medial leg, ankle, foot	Patellar	Test with ankle dorsiflexion
L5	Extensor hallux longus	Dorsal/plantar foot, 1st web space, lateral leg	Hamstring	Most commonly compressed lumbar root; test with hallux dorsiflexion
S1	Gastrocnemius	Lateral foot, posterior leg	Achilles	Test with ankle plantar flexion/toe walking
S2-4	Sphincter	Perianal sensation	Anal wink	Test tone to evaluate for cauda equina syndrome


Parotid gland
Facial artery and vein
Submandibular gland
Mylohyoid muscle
Hypoglossal nerve (XII)
Digastric muscle (anterior belly)
Lingual artery
External carotid artery
Internal carotid artery
Thyrohyoid muscle
Superior thyroid artery
Omohyoid muscle (superior belly) *(cut)*
Ansa cervicalis { Superior root
Inferior root
Sternohyoid muscle
Sternothyroid muscle
Internal jugular vein
Common carotid artery
Inferior thyroid artery
Vagus nerve (X)
Vertebral artery
Thyrocervical trunk
Subclavian artery and vein
Great auricular nerve
Lesser occipital nerve
Sternocleidomastoid muscle *(cut, turned up)*
Stylohyoid muscle
Digastric muscle (posterior belly)
C2 spinal nerve (ventral ramus)
Accessory nerve (XI)
C3 spinal nerve (ventral ramus)
Levator scapulae muscle
Middle scalene muscle
Anterior scalene muscle
C5 spinal nerve (ventral ramus)
Transverse cervical artery
Phrenic nerve
Omohyoid muscle (inferior belly) *(cut)*
Brachial plexus
Dorsal scapular artery
Suprascapular artery
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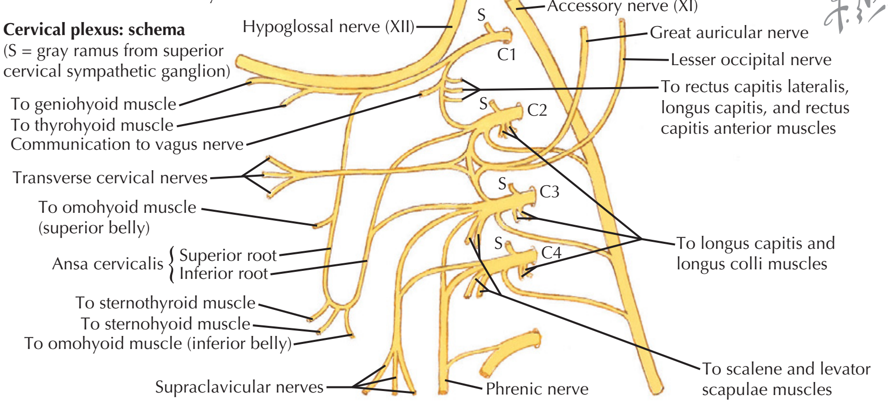
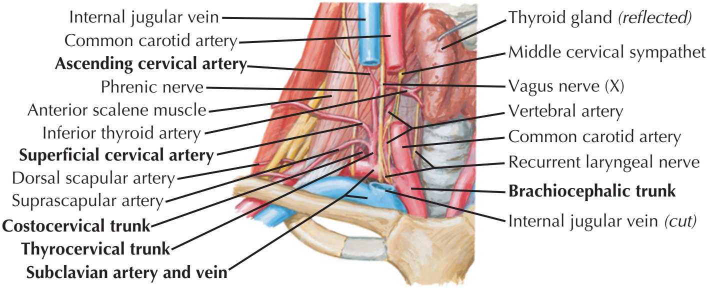
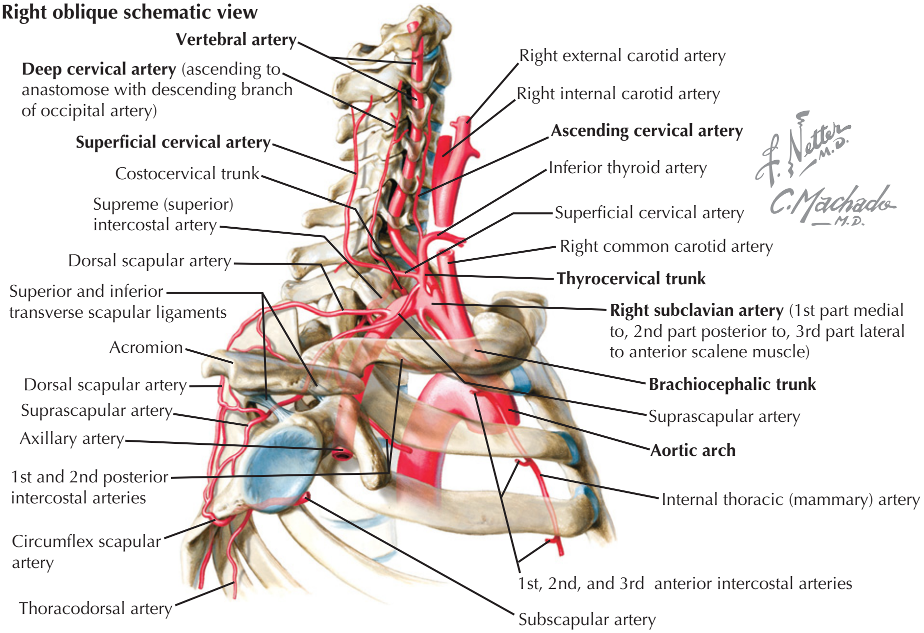

Cervical plexus: schema
(S = gray ramus from superior cervical sympathetic ganglion)
Hypoglossal nerve (XII)
S
C1
Accessory nerve (XI)
Great auricular nerve
Lesser occipital nerve
To rectus capitis lateralis, longus capitis, and rectus capitis anterior muscles
To geniohyoid muscle
To thyrohyoid muscle
Communication to vagus nerve
S
C2
Transverse cervical nerves
S
C3
To omohyoid muscle (superior belly)
S
C4
To longus capitis and longus colli muscles
Ansa cervicalis { Superior root
Inferior root
To sternothyroid muscle
To sternohyoid muscle
To omohyoid muscle (inferior belly)
Supraclavicular nerves
Phrenic nerve
To scalene and levator scapulae muscles

CERVICAL PLEXUS	
C1-C4 ventral rami (behind IJ and SCM)	
Lesser Occipital Nerve (C2-3): arises from posterior border of sternocleidomastoid *Sensory:* Superior region behind auricle *Motor:* None	**Supraclavicular** (C2-3): splits into 3 branches: anterior, middle, posterior *Sensory:* Over clavicle, outer trapezius and deltoid *Motor:* None
Great Auricular Nerve (C2-3): exits inferior to lesser occipital nerve, ascends on SCM *Sensory:* Over parotid gland and behind ear *Motor:* None	**Ansa Cervicalis** (C1-3): superior (C1-2) & inferior (C2-3) roots form loop *Sensory:* None *Motor:* Omohyoid Sternohyoid Sternothyroid
Tranverse Cervical Nerve (C2-3): exits inferior to greater auricular nerve, then to anterior neck *Sensory:* Anterior triangle of the neck *Motor:* None	**Phrenic Nerve** (C3-5):On anterior scalene, into thorax between subclavian artery and vein *Sensory:* Pericardium and mediastinal pleura *Motor:* Diaphragm

Right anterior dissection


Internal jugular vein
Common carotid artery
Ascending cervical artery
Phrenic nerve
Anterior scalene muscle
Inferior thyroid artery
Superficial cervical artery
Dorsal scapular artery
Suprascapular artery
Costocervical trunk
Thyrocervical trunk
Subclavian artery and vein
Thyroid gland *(reflected)*
Middle cervical sympathetic ganglion
Vagus nerve (X)
Vertebral artery
Common carotid artery
Recurrent laryngeal nerve
Brachiocephalic trunk
Internal jugular vein *(cut)*

Right oblique schematic view


Vertebral artery
Deep cervical artery (ascending to anastomose with descending branch of occipital artery)
Superficial cervical artery
Costocervical trunk
Supreme (superior) intercostal artery
Dorsal scapular artery
Superior and inferior transverse scapular ligaments
Acromion
Dorsal scapular artery
Suprascapular artery
Axillary artery
1st and 2nd posterior intercostal arteries
Circumflex scapular artery
Thoracodorsal artery
Right external carotid artery
Right internal carotid artery
Ascending cervical artery
Inferior thyroid artery
Superficial cervical artery
Right common carotid artery
Thyrocervical trunk
Right subclavian artery (1st part medial to, 2nd part posterior to, 3rd part lateral to anterior scalene muscle)
Brachiocephalic trunk
Suprascapular artery
Aortic arch
Internal thoracic (mammary) artery
1st, 2nd, and 3rd anterior intercostal arteries
Subscapular artery
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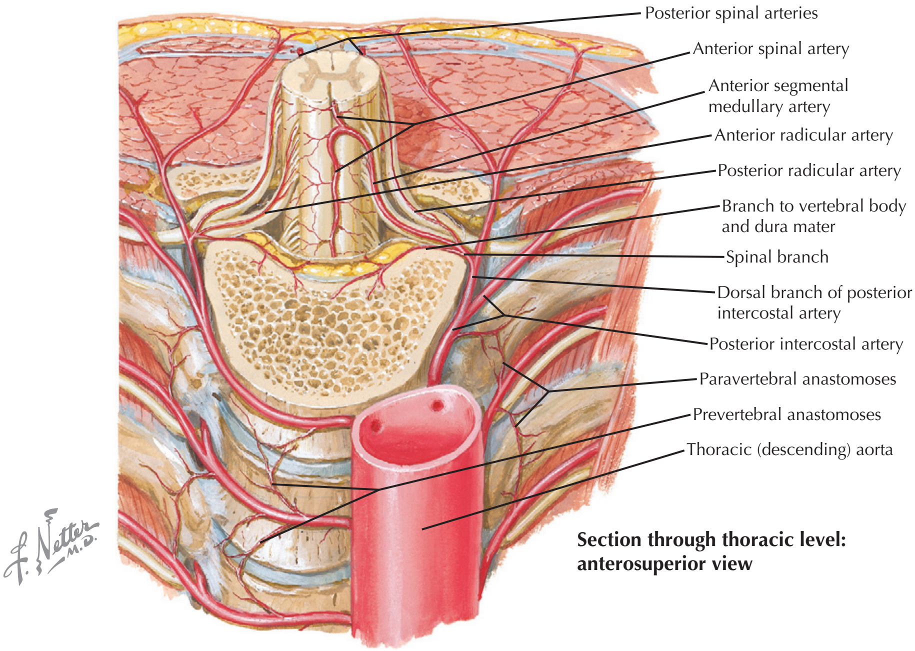
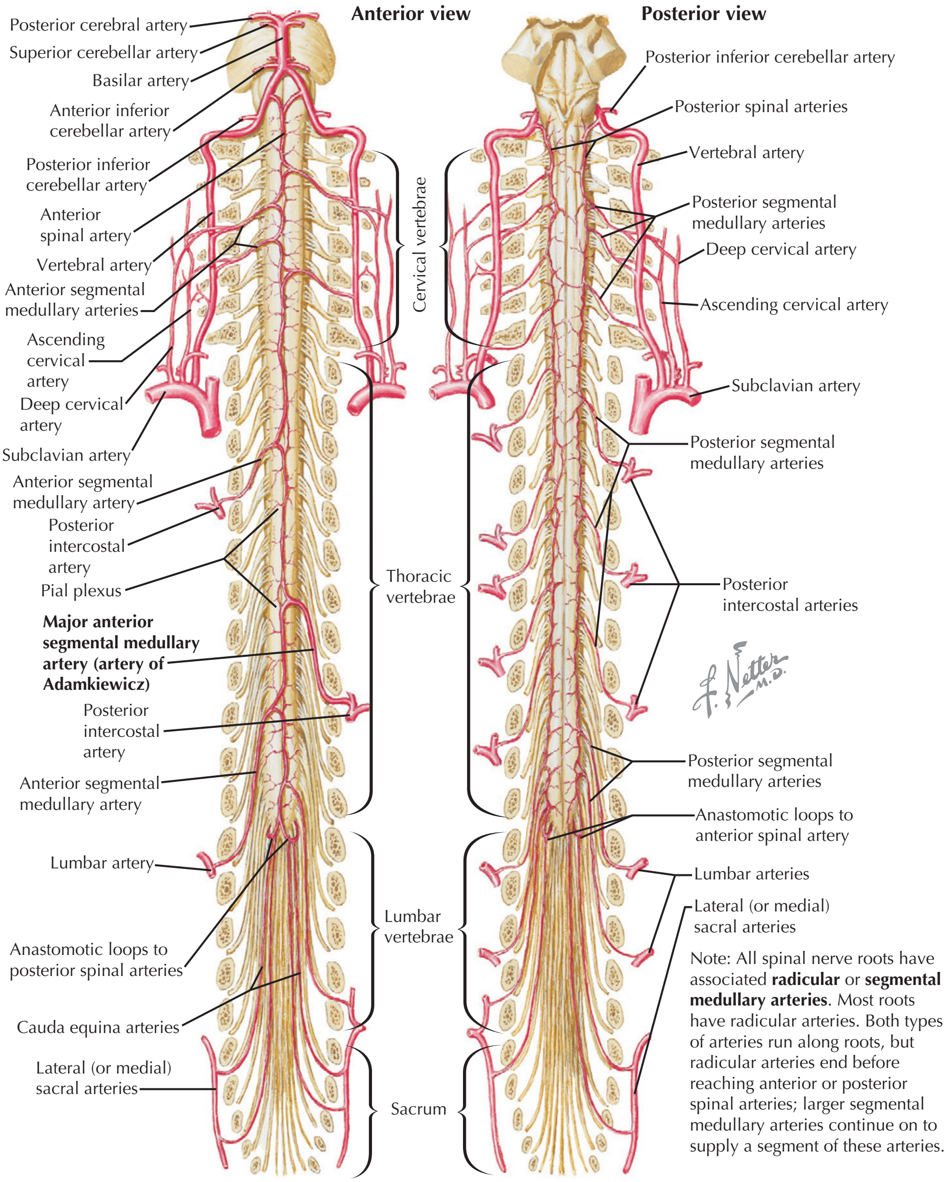
COURSE	BRANCHES	COMMENT/SUPPLY
	SUBCLAVIAN ARTERY	
Branches off aorta (L) or brachiocephalic trunk (R) b/w anterior and middle scalene muscles	**Vertebral arteries** (R & L)	Main arterial supply to the cervical spine and cord
	Thyrocervical trunk	Has 4 primary branches
	Ascending cervical	Runs with phrenic nerve on anterior scalene muscles
	Superficial cervical	Crosses posterior triangle of neck (scalenes, etc)
	Deep cervical	Off costocervical trunk, anastomoses w/ occipital artery
	VERTEBRAL ARTERY	
Enters foramen transversarium from C6 through C1 then runs in a groove on the atlas, then to brain stem to form basilar artery	**Anterior spinal artery**	Single midline artery supplies anterior ⅔ of spinal cord
	Posterior spinal arteries	2 paired arteries supply posterior ⅓ of spinal cord
	Anterior ascending	Give primary supply to odontoid
	Posterior ascending	Give primary supply to odontoid
	Ant. segmental medullary	Contribute to anterior spinal artery
	Post. segmental medullary	Contribute to posterior spinal arteries
Injury or infarct of the anterior or posterior spinal arteries can result in an anterior/central or posterior cord syndrome.		

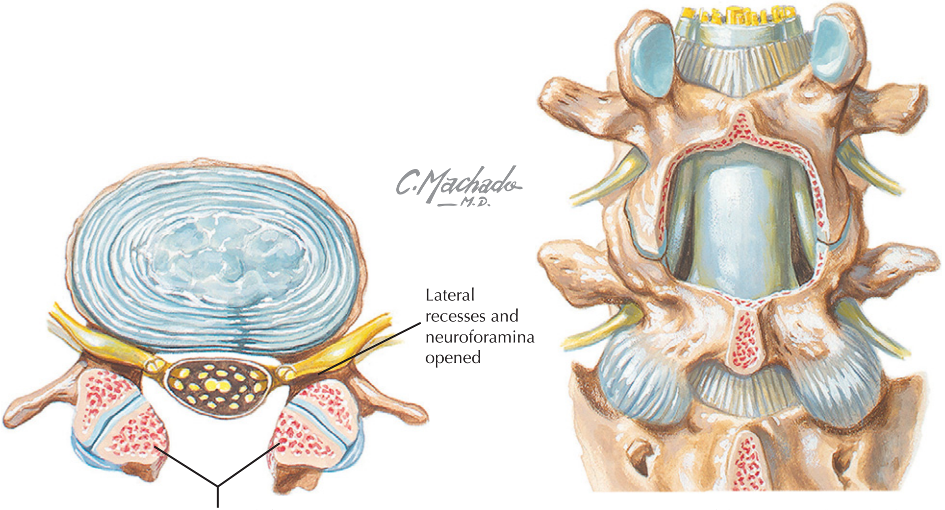

Posterior spinal arteries
Anterior spinal artery
Anterior segmental medullary artery
Anterior radicular artery
Posterior radicular artery
Branch to vertebral body and dura mater
Spinal branch
Dorsal branch of posterior intercostal artery
Posterior intercostal artery
Paravertebral anastomoses
Prevertebral anastomoses
Thoracic (descending) aorta

Section through thoracic level: anterosuperior view

COURSE	BRANCHES	COMMENT/SUPPLY
INTERCOSTAL(THORACIC)/LUMBAR ARTERY		
Paired arteries (R & L) branch off aorta, run posterior along vertebral bodies (between ribs in thoracic region)	Ventral branch Dorsal branch **Spinal branch** **Major anterior segmental medullary** (radicular)	To vertebral bodies To posterior elements and cord Supplies cord, nerve roots, and body "Artery of Adamkiewicz"—single medullary artery (usually left T10-T12) to ant. spinal artery is primary supply to thoracolumbar cord. Injury can cause cord ischemia/paralysis.
SPINAL BRANCH		
Branches off dorsal branch and enters intervertebral foramen	**Anterior radicular** **Posterior radicular** Postcentral branch Prelaminar branch	Runs on ventral root, anastomoses with anterior spinal artery Runs on dorsal root, anastomoses with posterior spinal artery Supplies vertebral body and dura Supplies lamina/posterior elements
ANTERIOR SPINAL		
Single midline artery supplies anterior ⅔ of spinal cord	Central (sulcal) branches Pial arterial plexus	Supplies central cord region Supplies peripheral ⅔ of spinal cord
POSTERIOR SPINAL		
Paired (R & L) arteries supply posterior ⅓ of spinal cord		Supplied by posterior medullary/radicular arteries


Anterior view
Posterior view
Posterior cerebral artery
Superior cerebellar artery
Basilar artery
Anterior inferior cerebellar artery
Posterior inferior cerebellar artery
Anterior spinal artery
Vertebral artery
Anterior segmental medullary arteries
Ascending cervical artery
Deep cervical artery
Subclavian artery
Anterior segmental medullary artery
Posterior intercostal artery
Pial plexus
Major anterior segmental medullary artery (artery of Adamkiewicz)
Posterior intercostal artery
Anterior segmental medullary artery
Lumbar artery
Anastomotic loops to posterior spinal arteries
Cauda equina arteries
Lateral (or medial) sacral arteries
Cervical vertebrae
Thoracic vertebrae
Lumbar vertebrae
Sacrum
Posterior inferior cerebellar artery
Posterior spinal arteries
Vertebral artery
Posterior segmental medullary arteries
Deep cervical artery
Ascending cervical artery
Subclavian artery
Posterior segmental medullary arteries
Posterior intercostal arteries
Posterior segmental medullary arteries
Anastomotic loops to anterior spinal artery
Lumbar arteries
Lateral (or medial) sacral arteries

Note: All spinal nerve roots have associated **radicular** or **segmental medullary arteries**. Most roots have radicular arteries. Both types of arteries run along roots, but radicular arteries end before reaching anterior or posterior spinal arteries; larger segmental medullary arteries continue on to supply a segment of these arteries.



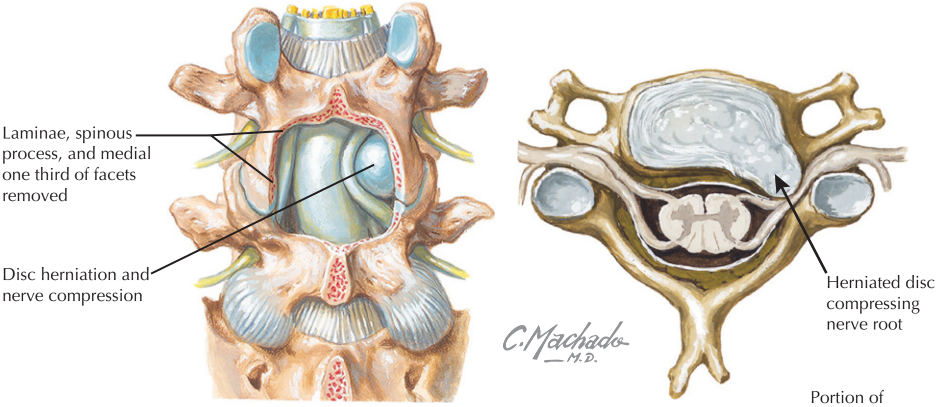
Spinal stenosis: Laminectomy

Laminectomy defect

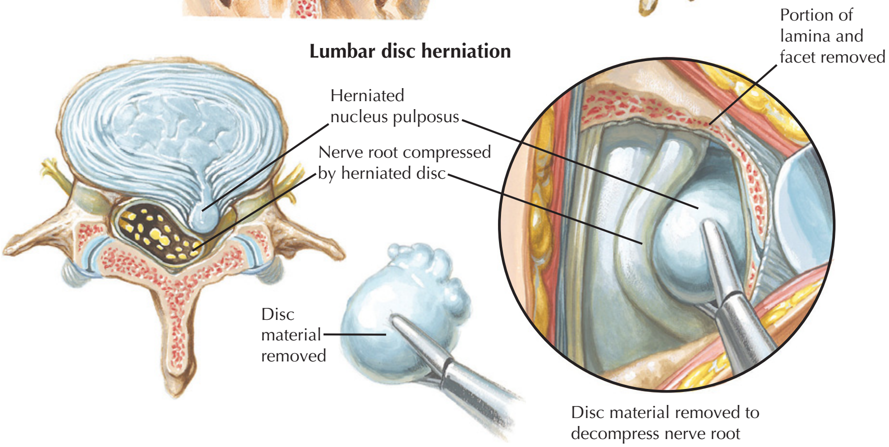
Postoperative view of decompressed vertebral canal

DESCRIPTION	Hx & PE	WORKUP	TREATMENT
CERVICAL STRAIN			
• Strain or spasm of cervical musculature • Often from MVA ("whiplash") or overuse	**Hx:** Pain (nonradiating) **PE:** Decreased ROM, muscle tenderness, normal neurologic exam	**XR:** C-spine series: usually normal **MR:** Usually not needed	• Rest, NSAIDs, physical therapy, usually 2-6wk • Can consider limited soft collar immobilization
LOW BACK PAIN			
• #2 medical complaint in U.S. • Multiple etiologies: muscle strain, annular tear, early spondylosis, or degenerative disc disease • Common workman compensation/disability complaint	**Hx:** Pain (may radiate to buttocks, not below knee) **PE:** Limited ROM, muscle (erector spinae) spasm/tenderness, normal neurologic exam; test for Waddell's signs	**XR:** L-spine series: usually normal **MR:** Usually not needed	• "Red flags" indicate further workup: fever/chills, radiculopathy, abnormal neurologic exam • Rest, NSAIDs, physical therapy, usually 2-6wk • Can consider lumbar brace
SPINAL STENOSIS			
• Narrowing of spinal canal results in cord/root compression • Causes: hypertrophy of facet capsule or ligamentum flavum, bulging disc, DDD/osteophytes	**Hx:** Pain, paresthesias relieved by sitting/forward leaning (neurogenic claudication) **PE:** Pain with back extension, do good neurologic exam	**XR:** L-spine series: DDD, facet DJD **CT:** Canal narrowing **MR:** Evaluate cord/root compression	• Activity modification, NSAIDs • PT— flexion exercises • Nerve root blocks/epidural injection • Decompression (laminectomy +/− partial facetectomy)

Cervical disc herniation

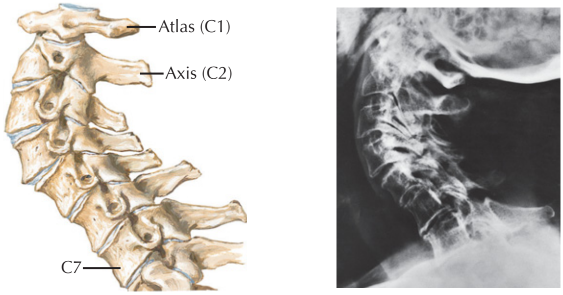

Laminae, spinous process, and medial one third of facets removed
Disc herniation and nerve compression
Herniated disc compressing nerve root
C. Machado M.D.

Lumbar disc herniation


Portion of lamina and facet removed
Herniated nucleus pulposus
Nerve root compressed by herniated disc
Disc material removed
Disc material removed to decompress nerve root

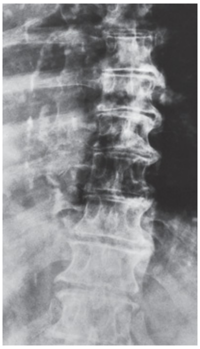
DESCRIPTION	Hx & PE	WORKUP	TREATMENT
HERNIATED NUCLEUS PULPOSUS (HNP)			
• Protrusion of nucleus pulposus through torn annulus fibers • Lumbar: L4-5 #1, traversing root affected except in far lateral herniation (exiting root) • Thoracic: rare • Cervical: associated with spondylosis • Can compress cord or roots	**Hx:** Neck/back pain, +/– extremity (radiating) pain, paresthesias, and weakness **PE:** Variable: decreased ROM, spinal tenderness Cervical: +/– Spurling's Lumbar: +/– straight leg raise **Neuro:** Radicular findings	**XR:** Often normal +/– disc space narrowing or spondylosis **MR:** Best study to show protruding disc and nerve or cord compression	• Rest, activity modification • NSAIDs (limit narcotic use) • Physical therapy • Epidural steroid injections • Diskectomy +/– fusion: ◦ Failed conservative treatment ◦ Progressive neurologic deficit ◦ Cauda equina syndrome
CAUDA EQUINA SYNDROME			
• Compression of cauda equina • Usually from large midline disc herniation or extrusion • Bowel & bladder dysfunction • Surgical emergency	**Hx/PE:** "Saddle" (perianal) anesthesia, lower extremity numbness/weakness, decreased rectal tone	**XR:** Normal or disc space narrowing **MR:** Study of choice: compression of cauda equina	• Emergency surgical decompression-laminectomy/diskectomy • (Prognosis is still guarded even with prompt diagnosis and treatment.)

Spine Involvement in Osteoarthritis

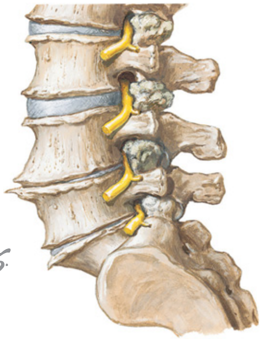


Extensive thinning of cervical discs and hyperextension deformity with narrowing of intervertebral foramina. Lateral radiograph reveals similar changes

Degenerative Disc Disease



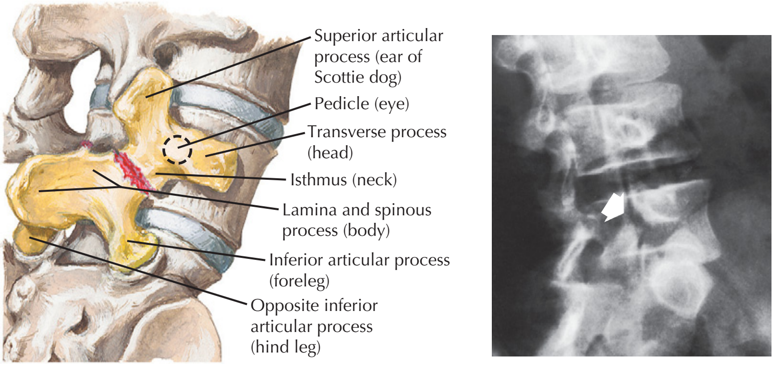
Radiograph of thoracic spine shows narrowing of intervertebral spaces and spur formation



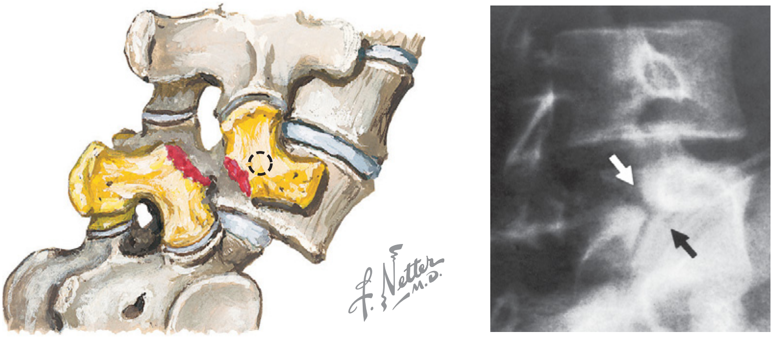
Degeneration of lumbar intervertebral discs and hypertrophic changes at vertebral margins with spur formation. Osteophytic encroachment on intervertebral foramina compresses spinal nerves

DESCRIPTION	Hx & PE	WORKUP	TREATMENT
CERVICAL SPONDYLOSIS			
• Degenerative changes in discs, facets, and uncovertebral joints • C5-6 #1, C6-7 #2; men>women • Causes axial/neck pain • Can result in cord or root compression: myelo/radiculopathy	**Hx:** Neck pain, +/– UE pain, paresthesias, and/or weakness **PE:** Decreased ROM, + Spurling's test, +/– neurologic symptoms	**XR:** Loss of lordosis/ cervical straightening, loss of disc space **MR:** Shows disc degeneration or herniation	• NSAIDs, activity modification • Physical therapy, +/– traction • Epidural or facet injections • Surgical ◦ Anterior diskectomy and fusion (ACDF) ◦ Posterior decompression/ fusion
DEGENERATIVE DISC DISEASE			
• Disc properties change (decr. H_2O, proteins altered, etc) leads to decr. mechanical properties • Ligaments/facets assume greater load, can be source of pain • Natural process: unclear why only some have pain	**Hx:** Back pain without radiculopathy **PE:** +/– decreased ROM or painful ROM, normal tension signs (straight leg/bowstring tests)	**XR:** Can be normal or disc height loss **MR:** Low signal (black disc), decreased height **Discography:** confirms disc as pain source (used for preop. eval.)	• Rest, activity modification, NSAIDs, +/– muscle relaxers • Physical therapy: stretching, strengthening, weight control • Consider lumbar bracing • Surgical: lumbar fusion or disc replacement are options

Spondylolysis and Spondylolisthesis

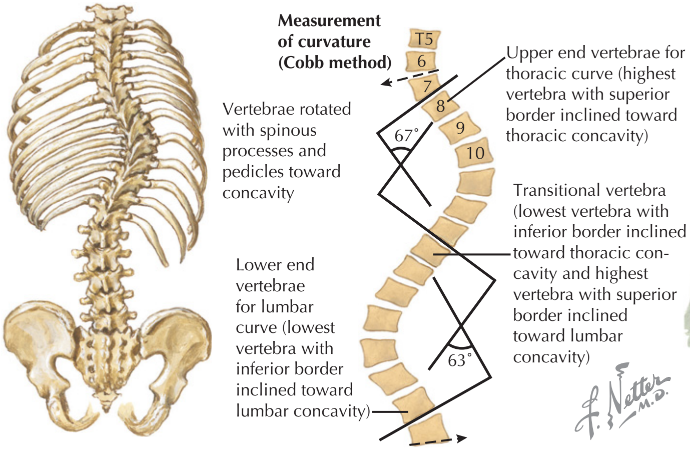

Superior articular process (ear of Scottie dog)
Pedicle (eye)
Transverse process (head)
Isthmus (neck)
Lamina and spinous process (body)
Inferior articular process (foreleg)
Opposite inferior articular process (hind leg)

Spondylolysis without spondylolisthesis. Posterolateral view demonstrates formation of radiographic Scottie dog. On lateral radiograph, dog appears to be wearing a collar



Isthmic type spondylolisthesis. Anterior subluxation of L5 on sacrum due to fracture of isthmus. Note that gap is wider and dog appears decapitated

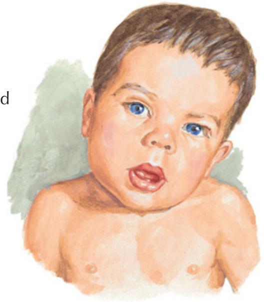
DESCRIPTION	Hx & PE	WORKUP	TREATMENT
SPONDYLOLYSIS			
• Defect or fracture of pars interarticularis (without slip) • Assoc. w/ hyperextension sports (gymnasts, linemen) • Common in pediatrics • L5 most common site	**Hx:** Insidious onset of low back pain, worse with activities **PE:** Decreased lumbar lordosis, +/– tight hamstrings	**XR:** L-spine obliques "Scottie dog has a collar/neck" **CT:** For subtle lesions **SPECT:** Indicates if lesion has healing capacity	• Rest, activity modification • Physical therapy: esp. stretching, flexion exercises • Lumbar brace • Surgery uncommon without advanced spondylolisthesis
SPONDYLOLISTHESIS			
• Slippage of one vertebra on adjacent vertebrae • Six types: ∘ Dysplastic (congenital) ∘ Isthmic (#1, L5-S1, hyperextension) ∘ Degenerative (elderly) ∘ Traumatic (acute pars fx) ∘ Pathologic ∘ Post-surgical	**Hx:** Insidious onset of low back pain, worse with activities +/– radicular symptoms **PE:** Decreased ROM, often painful (esp. extension) +/– sensory or motor findings	**XR:** Lateral view used to determine grade (% of vertebral body slipped) Grade 1: 0-25% Grade 2: 25-50% Grade 3: 50-75% Grade 4: >75% **CT/SPECT:** For subtle defects and healing potential	**Low grade (1-2):** • Rest, activity modification • Physical therapy • Lumbar bracing **High grade (3-4):** • Peds: prophylactic posterolateral (PL) fusion • Adults: decompression and PL fusion



Scoliosis

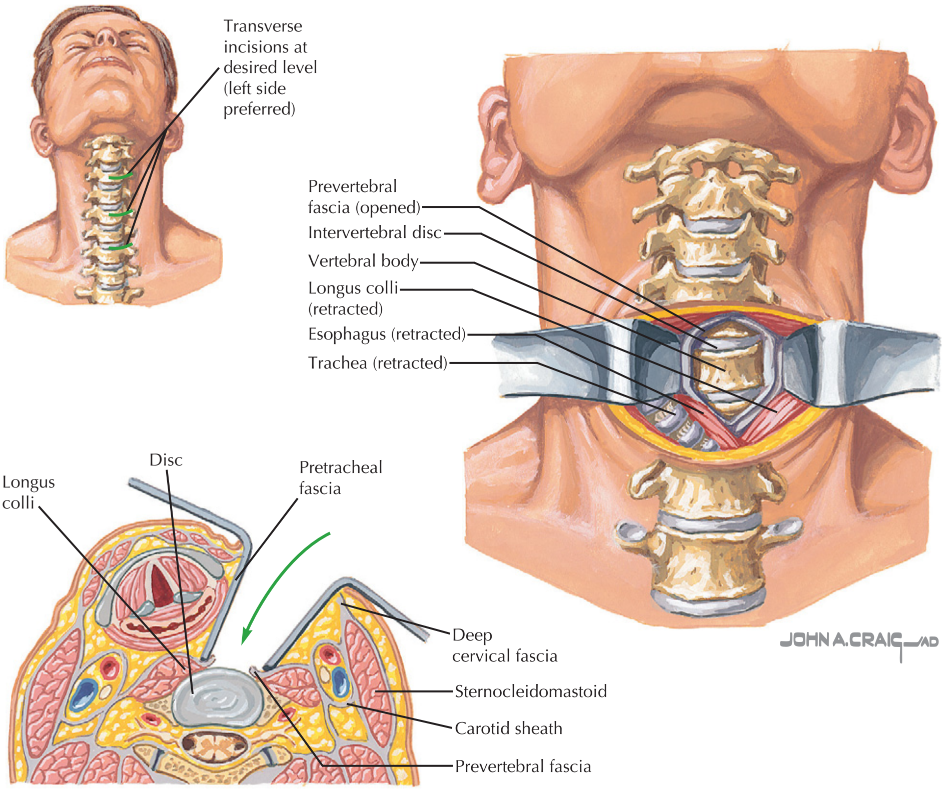
Measurement of curvature (Cobb method)
T5
6
7
8
9
10
67°
63°
Vertebrae rotated with spinous processes and pedicles toward concavity
Upper end vertebrae for thoracic curve (highest vertebra with superior border inclined toward thoracic concavity)
Transitional vertebra (lowest vertebra with inferior border inclined toward thoracic concavity and highest vertebra with superior border inclined toward lumbar concavity)
Lower end vertebrae for lumbar curve (lowest vertebra with inferior border inclined toward lumbar concavity)

Torticollis (Wryneck)



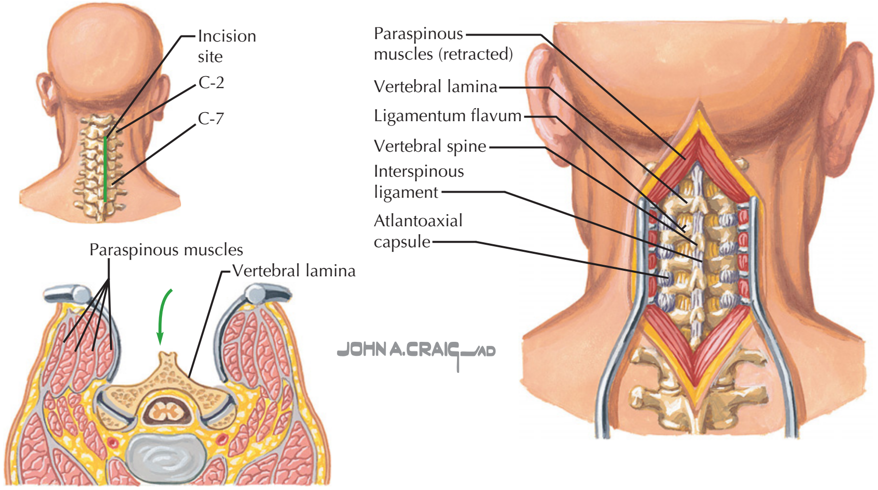
DESCRIPTION	EVALUATION	TREATMENT
MYELODYSPLASIA		
• Incomplete spinal cord development (neural tube closure defect) • 4 types depending on severity • Associated w/elevated maternal AFP • Prenatal folic acid decreases incidence • Associated with multiple deformities (spine, hips, knees, and feet) • Often associated with latex allergy	**Hx:** Can be diagnosed intrauterine **PE/XR:** Based on type of defect: 1. Spina bifida 2. Meningocele 3. Myelomeningocele 4. Rachischisis Symptoms/exam based on lowest functional level (intact L4 allows for ambulation)	• Must individualize for each patient • Most need ambulation aids and/or orthoses • Muscle balancing (releases) • Individual deformities ◦ Scoliosis: most need fusion ◦ Hips: keep them contained ◦ Feet: release or arthrodesis
SCOLIOSIS		
• Lateral bending & rotation of the spine • Types: ◦ I. Congenital (abnormal vertebrae) ◦ II. Idiopathic: #1, often +fam hx; ◦ Infantile: <3y.o., M>F; ◦ Juvenile: 3-10y.o.; ◦ Adolescent: #1, F>M, R>L; ◦ III. Neuromuscular: associated with neuromuscular disease • Curve progression evaluated by: ◦ Curve magnitude: x-ray/Cobb angle ◦ Skeletal maturity: use Risser stage • Classifications: King & Moe, Lenke	**Hx:** Patient or parents may notice asymmetry of back; found on school screening; +/− pain; neuro sx rare **PE:** Gross or subtle spinal deformity, + forward bending test; neurologic findings rare (increased with left-sided curves) **XR:** Full length spinal films: use Cobb technique to determine angle Bending films used to determine flexibility of the curve/deformity	• School screening is effective • Congenital: progression & need for surgery depend on severity/type • Idiopathic: depends on curve & age ◦ <25°: observation ◦ 25-40°: bracing ◦ >40°: spinal fusion • Juvenile type often needs fusion • Neuromuscular: often require longer fusions, both anterior & posterior
TORTICOLLIS		
• Head tilted, chin rotated opposite side • Sternocleidomastoid (SCM) contracture • Etiology unknown • Associated with intrauterine position • Associated with other disorders	**Hx:** Parents notice deformity, +/− lump in the neck (on sternocleidomastoid) **PE:** Head tilted/rotated, +/− SCM lump. +/− cranial and/or facial asymmetry **XR:** Spine/hips: r/o other deformities	• Rule out any associated disorders • Physical therapy/stretching (SCM) • Helmet may be needed for cranium • Surgical release if persistent • Poor eye development is concern

Anterior Approach to Cervical Spine

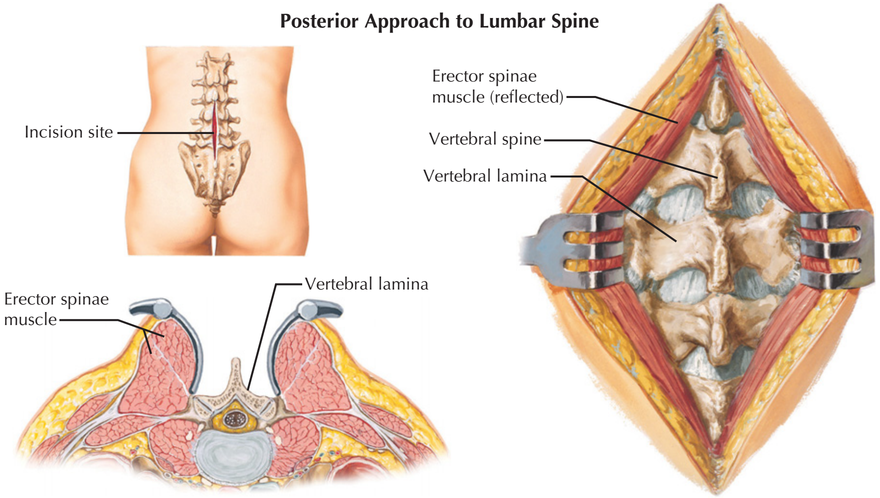

Transverse incisions at desired level (left side preferred)
Prevertebral fascia (opened)
Intervertebral disc
Vertebral body
Longus colli (retracted)
Esophagus (retracted)
Trachea (retracted)
JOHN A.CRAIG AD
Longus colli
Disc
Pretracheal fascia
Deep cervical fascia
Sternocleidomastoid
Carotid sheath
Prevertebral fascia

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
ANTERIOR APPROACH			
• Anterior cervical discectomy & fusion (ACDF) for cervical spondylosis and/or HNP • Tumor or biopsy	**Superficial** Deep cervical fascia: SCM goes lateral Pretracheal fascia: carotid sheath goes lateral **Deep** Prevertebral fascia between longus collis muscles (right & left)	• Recurrent laryngeal n. • Sympathetic n. • Carotid artery • Internal jugular • Vagus nerve • Inferior thyroid artery	• Access C3 to T1 • Right recurrent laryngeal nerve more susceptible to injury; many surgeons approach on left side • Thyroid arteries limit extension of the approach

Posterior Approach to Cervical Spine


Incision site
C-2
C-7
Paraspinous muscles
Vertebral lamina
Paraspinous muscles (retracted)
Vertebral lamina
Ligamentum flavum
Vertebral spine
Interspinous ligament
Atlantoaxial capsule
JOHN A.CRAIG AD

Posterior Approach to Lumbar Spine


Incision site
Erector spinae muscle (reflected)
Vertebral spine
Vertebral lamina
Erector spinae muscle
Vertebral lamina

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
POSTERIOR APPROACH			
Cervical			
• Posterior fusion/spondylosis • Facet dislocation	Left and right paracervical muscles (posterior cervical rami)	• Spinal cord • Nerve roots • Posterior rami • Vertebral artery • Segmental vessels	• Most common C-spine approach • Mark level of pathology with radiopaque marker preop to assist finding the appropriate level intraoperatively
Lumbar			
• Herniated disc (HNP)/nerve compression & diskectomy • Lumbar fusion	Left and right paraspinal muscles (dorsal rami)	• Segmental vessels to paraspinals	• Incision is along the spinous processes

CHAPTER 3
Shoulder

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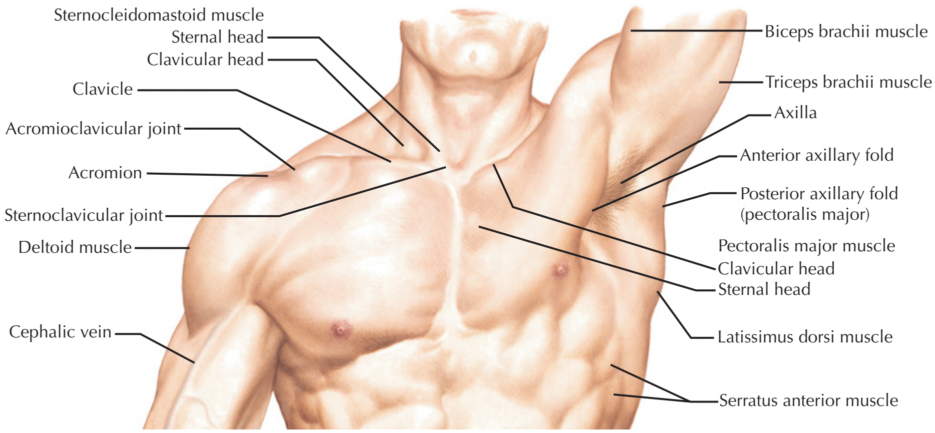
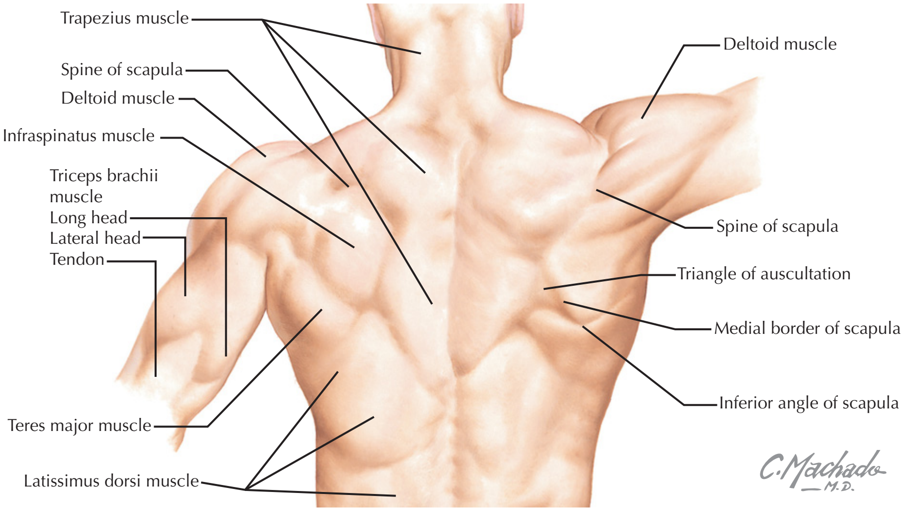
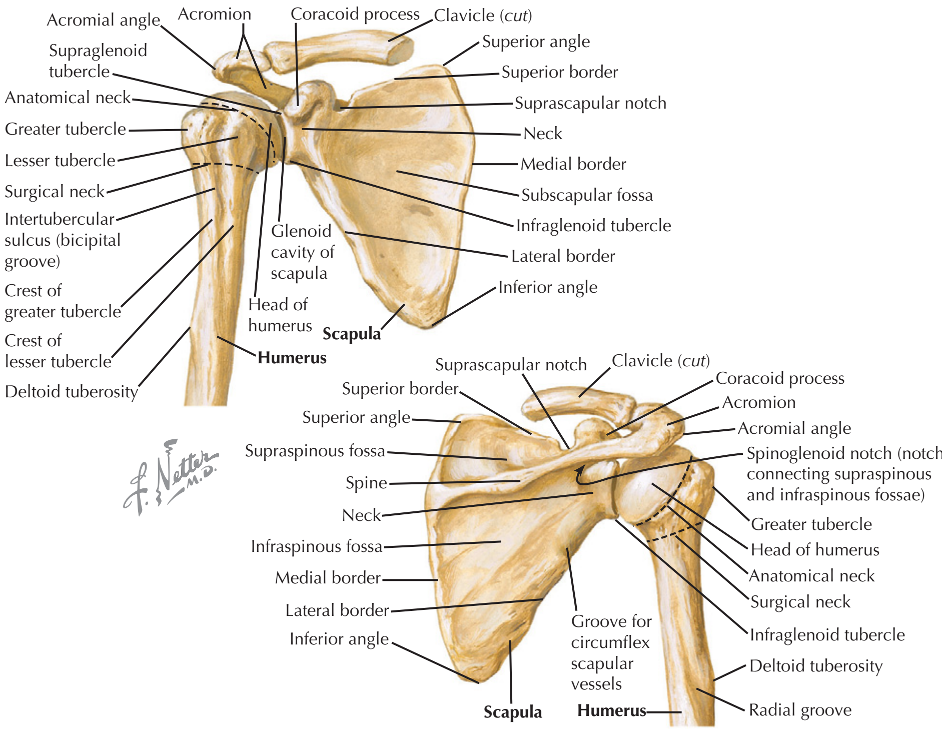
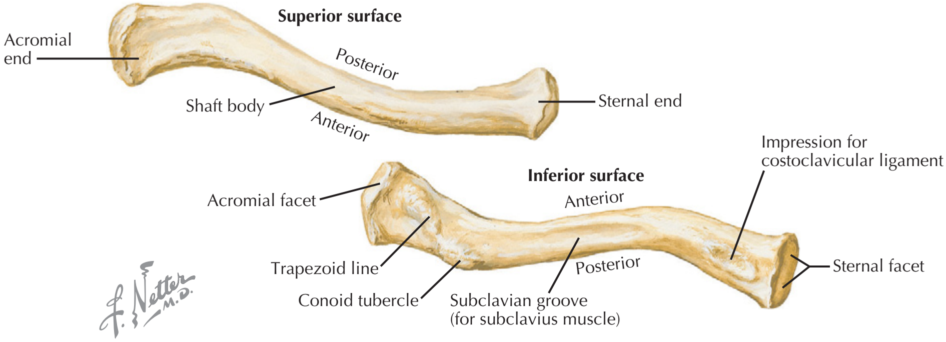

Sternocleidomastoid muscle
Sternal head
Clavicular head
Clavicle
Acromioclavicular joint
Acromion
Sternoclavicular joint
Deltoid muscle
Cephalic vein
Biceps brachii muscle
Triceps brachii muscle
Axilla
Anterior axillary fold
Posterior axillary fold (pectoralis major)
Pectoralis major muscle
Clavicular head
Sternal head
Latissimus dorsi muscle
Serratus anterior muscle

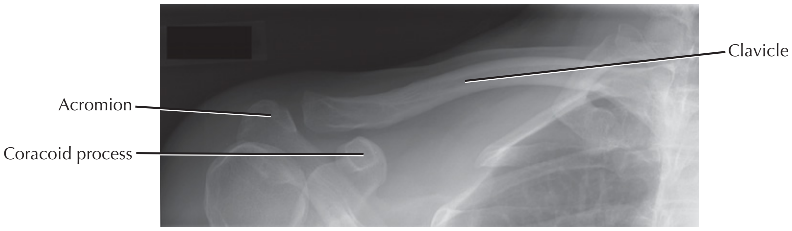

Trapezius muscle
Spine of scapula
Deltoid muscle
Infraspinatus muscle
Triceps brachii muscle
Long head
Lateral head
Tendon
Teres major muscle
Latissimus dorsi muscle
Deltoid muscle
Spine of scapula
Triangle of auscultation
Medial border of scapula
Inferior angle of scapula
C. Machado M.D.

STRUCTURE	CLINICAL APPLICATION
Sternoclavicular (SC) joint	Uncommon site of infection or dislocation
Clavicle	Subcutaneous bone: most common bone to fracture
Acromioclavicular (AC) joint	Common site of "shoulder separation" or degenerative joint disease/pain
Acromion	Landmark of shoulder (especially for injections, e.g., subacromial)
Deltoid muscle	Can test muscle function for axillary nerve motor function
Trapezius	Common site of pain; weakness results in lateral scapular winging
Serratus anterior	Weakness/palsy results in medial scapular winging
Pectoralis major	Can rupture off humeral insertion, results in a defect in the axillary fold
Cephalic vein	Lies in the deltopectoral interval
Spine of scapula	More prominent with supra/infraspinatus muscle wasting (suprascapular nerve palsy)
Inferior angle of scapula	May "wing" medially or laterally if muscles are weak (nerve palsies)

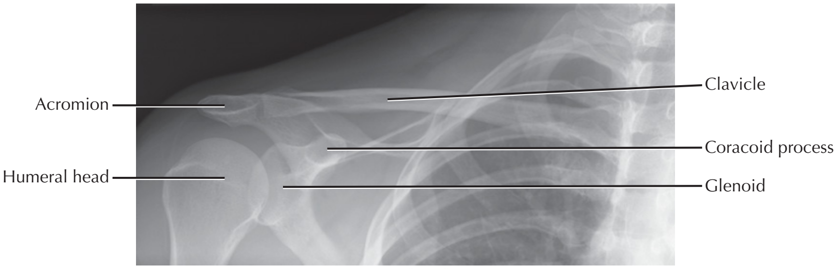

Acromial angle
Acromion
Coracoid process
Clavicle (cut)
Supraglenoid tubercle
Superior angle
Superior border
Anatomical neck
Suprascapular notch
Greater tubercle
Neck
Lesser tubercle
Medial border
Surgical neck
Subscapular fossa
Intertubercular sulcus (bicipital groove)
Infraglenoid tubercle
Glenoid cavity of scapula
Lateral border
Crest of greater tubercle
Inferior angle
Head of humerus
Crest of lesser tubercle
Scapula
Humerus
Deltoid tuberosity
Suprascapular notch
Clavicle (cut)
Coracoid process
Superior border
Acromion
Superior angle
Acromial angle
Supraspinous fossa
Spinoglenoid notch (notch connecting supraspinous and infraspinous fossae)
Spine
Greater tubercle
Neck
Head of humerus
Infraspinous fossa
Anatomical neck
Medial border
Surgical neck
Lateral border
Groove for circumflex scapular vessels
Infraglenoid tubercle
Inferior angle
Deltoid tuberosity
Radial groove
Scapula
Humerus
F. Netter M.D.

CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
		SCAPULA		
• Flat, triangular bone	**Primary**			• Suprascapular nerve can be compressed in suprascapular notch (denervates SS & IS) or in the spinoglenoid notch (denervates IS only)
• Spine posteriorly separates two fossae (supra/infraspinatus)	Body	8wk fetal	15-20yr	
• Two notches	**Secondary**			• Suprascapular & spinoglenoid notches
• Coracoid process anteriorly	Coracoid	1yr	All fuse between 15-20yr	• Coracoid is the "lighthouse" to the shoulder
• Glenoid: pear shaped	Glenoid	15-18yr		• Glenoid: 5-7° retroverted, 5° superior tilt
• Acromion: hook-shaped lateral prominence	Acromion	15-18yr		• Unfused acromion results in os acromiale
	Inferior angle	15-18yr		• Body of scapula is very thin, angle is thicker
		PROXIMAL HUMERUS		
• Head is retroverted: 35°	**Primary**	8-9wk fetal	Birth	• Anatomic neck fxs: risk for osteonecrosis
• Anatomic and surgical necks	Shaft			• Surgical neck: common fx site (especially in the elderly)
• Head/neck angle: 130°	**Secondary**			• 80% of bone growth from proximal physis; proximal fxs in children have great remodeling potential
• Two tuberosities: Greater is lateral Lesser is anterior	Proximal (3):		17-20yr	
	Head	Birth		• Greater tuberosity: insertion site of supraspinatus, infraspinatus, teres minor
	Gtr tuberosity	1-2yr		• Lesser tuberosity: insertion site of subscapularis
• Bicipital groove between gtr and lsr tuberosities: bicep tendon	Lsr tuberosity	3-4yr		

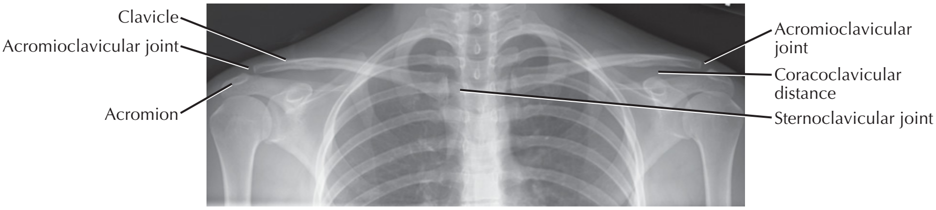

Superior surface
Acromial end
Posterior
Shaft body
Anterior
Sternal end
Inferior surface
Impression for costoclavicular ligament
Acromial facet
Anterior
Trapezoid line
Posterior
Sternal facet
Conoid tubercle
Subclavian groove (for subclavius muscle)


Clavicle
Acromion
Coracoid process

X-ray, clavicle

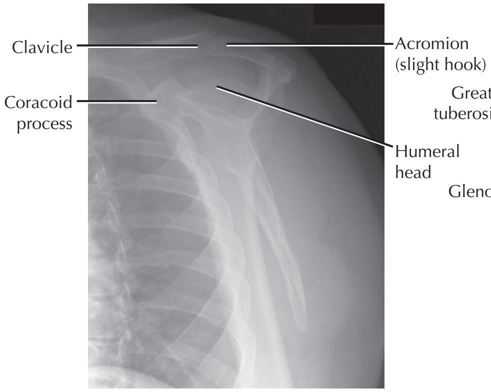

Clavicle
Acromion
Coracoid process
Humeral head
Glenoid

X-ray, clavicle

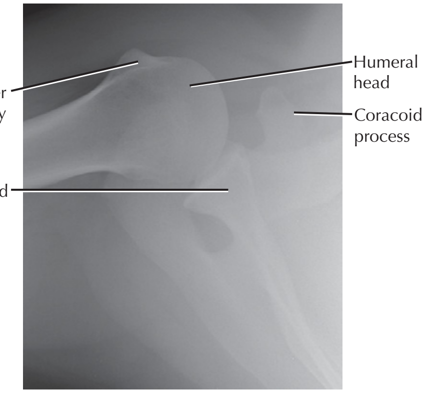

Clavicle
Acromioclavicular joint
Acromion
Acromioclavicular joint
Coracoclavicular distance
Sternoclavicular joint

X-ray, AC joints

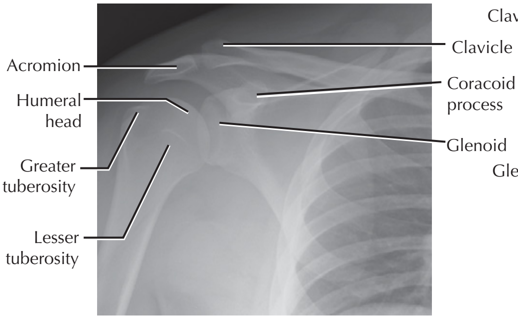
CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
		CLAVICLE		
• S-shaped cylindrical bone • Middle ⅓ is narrowest, no muscle insertions • Clavicle widens laterally • No true medullary canal	**Primary** (2)			• Only link from upper extremity to axial skeleton • Most commonly fractured bone in body; middle ⅓ is most common location of fracture (80%) • First bone to ossify, last to fuse • Starts as intramembranous, then finishes as membranous ossification
	Medial & lateral	7wk fetal	9wk fetal	
	Secondary			
	Sternal	18-20yr	19-25yr	
	Acromial	18-20yr	19-22yr	


Clavicle
Coracoid process
Acromion (slight hook)
Humeral head

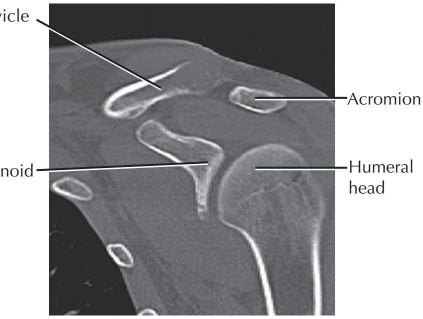
X-ray, scapular


Greater tuberosity
Glenoid
Humeral head
Coracoid process

X-ray axillary, lateral


Acromion
Humeral head
Greater tuberosity
Lesser tuberosity
Clavicle
Coracoid process
Glenoid

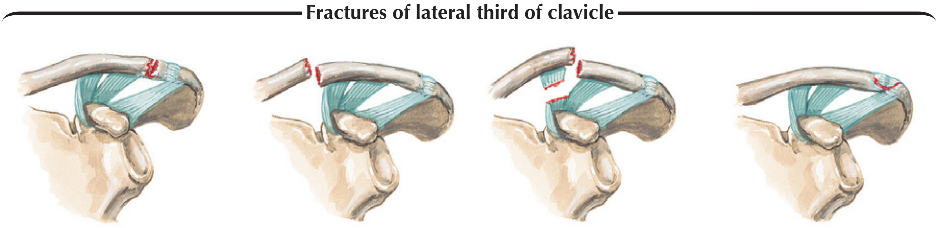
X-ray, AP


Clavicle
Glenoid
Acromion
Humeral head

Coronal, CT

RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
CLAVICLE			
Clavicle (2 view)	AP w/caudal & cephalic tilt	Clavicle	Fracture, DJD of ACJ
Zanca	AP (of ACJ) w/10° cephalic tilt	Acromioclavicular joint	ACJ pathology (DJD, fx)
Stress views	Both ACJs w/w-out weights	Acromioclavicular joints	ACJ separation/instability
Serendipity	40° cephalic tilt manubrium	Sternoclavicular joint	Sternoclavicular pathology
SHOULDER			
AP	Plate perpendicular to scapula	Glenohumeral joint space	Trauma (fx/dx), arthritis
Axillary lateral	Abduct arm, beam into axilla	Glenoid/humeral head position	Dislocations, Hill-Sachs lesion
Scapular Y	Beam parallel to scapula	Humeral head position	Trauma, acromion type
Supraspinatus outlet	Scapular Y w/10° caudal tilt	Acromion morphology	Hooked acromion (type 3) is assoc. w/ impingement synd.
Stryker notch	Hand on head, 10° cephalic tilt	Humeral head	Hill-Sachs lesion
West point	Prone, beam into axilla	Anterior inferior glenoid	Bony Bankart lesion
OTHER STUDIES			
CT	Axial, coronal, sagittal	Articular congruity, fx fragment position	Fractures (esp. proximal humerus, glenoid/intraarticular)
MRI	Sequence protocols vary	Soft tissues (tendons, labrum)	Rotator cuff or labral tears

Fractures of lateral third of clavicle



Type I. Fracture with no disruption of ligaments and therefore no displacement. Treated with simple sling for few weeks

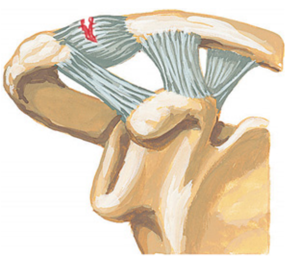
Type IIA. Fracture is medial to ligaments. Both ligaments are intact.

Type IIB. Fracture is between ligaments; coroid is disrupted, trapezoid is intact. Medial fragment may elevate.

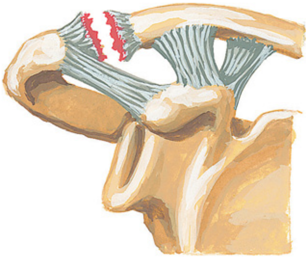
Type III. Fracture through acromioclavicular joint; no displacement. Often missed and may later cause painful osteoarthritis requiring resection arthroplasty

F. Netter M.D.
K. Marzen

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
CLAVICLE FRACTURE			
• Most common fx • 80% in middle third (group 1) • 15% group 2, 5% group 3 • Mechanism: fall onto shoulder (e.g., football, hockey) • Clavicle is unfused until early 20's, periosteal sleeve avulsion fx can result distally	**Hx:** Trauma/fall, pain **PE:** Swelling, tenderness. +/− tenting of skin/clinical deformity; do thorough neurovascular exam **XR:** 2 views of clavicle (evaluate for shortening) **CT:** Rarely needed	• Group 1: middle 1/3 • Group 2: distal 1/3 ◦ Type 1: lateral to CC ligaments ◦ Type 2a: medial to CC ligaments ◦ Type 2b: between CC ligaments (conoid torn, trapezoid intact) ◦ Type 3: fx into ACJ • Group 3: proximal 1/3	• Closed treatment/sling for most groups 1& 3 fxs • ORIF for fxs severely shortened, tented, open, associated with vascular injuries • ORIF for most group 2/type 2 distal fxs
COMPLICATIONS: Nonunion (esp. distal/group 2 fx); vascular or nerve injury			
SCAPULA FRACTURE			
• Mechanism: high-energy trauma • Uncommon injury • Young males most common • >85% have associated injuries: pulmonary contusion, pneumothorax • Good healing potential provided by surrounding muscles	**Hx:** Trauma (e.g., MVA), pain in back and/or shoulder **PE:** Swelling, tenderness to palpation, decreased ROM **XR:** AP/axillary lateral/scapular Y; CXR **CT:** Intraarticular/glenoid fractures, displaced body fractures	• Anatomic classification: A-G • Ideberg (glenoid fx) ◦ Type I: anterior avulsion fx ◦ Type II: transverse/oblique fx through glenoid; exits inferiorly ◦ Type III: oblique fx through glenoid, exits superiorly ◦ Type IV: transverse fx exits through the scapula body ◦ Type V: types II + IV	• Closed treatment with sling for 2wk for most fxs, then early ROM • ORIF for displaced, unstable, or large (>25%) intraarticular or angulated neck fxs
COMPLICATIONS: Associated injuries: Rib fracture #1, pulmonary contusion, pneumothorax, vascular or brachial plexus			



Grade 1



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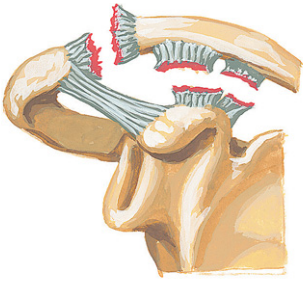

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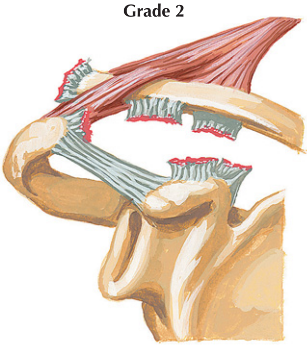
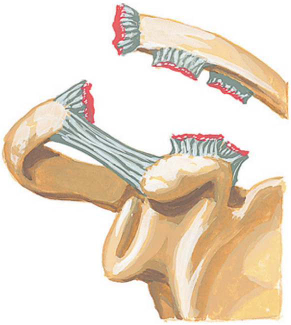
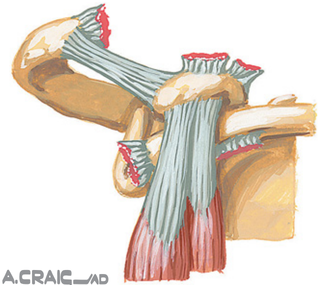


Grade 4



JOHN A. CRAIG_MD

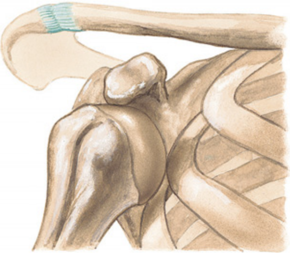
Grade 5



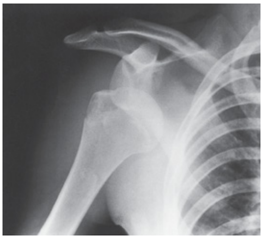
Grade 6

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
ACROMIOCLAVICULAR SEPARATION			
• Mechanism: fall onto shoulder (e.g., football, bicycles, etc) • Progression from isolated AC ligament injury to combined AC and CC (coracoclavicular) ligament disruption with varying clavicle displacement • Aka "shoulder separation"	**Hx:** Fall/direct blow, pain, swelling, +/− popping **PE:** AC tenderness, +/− instability & deformity **XR:** AC joint (+/− stress views, esp. grade II) (measure CC distance) **MR:** Evaluate CC ligaments	Rockwood grade: I. AC ligament sprain II. AC tear, CC intact III. AC & CC ligament tears ≤ 100% superior displacement IV: Grade III w /posterior displacement V: Grade III ≤ 300% superior displacement VI: Grade III w/ inferior displacement	• Grades I & II: sling, rest, physical therapy • Grade III: controversial. Nonoperative for most, CC reconstruction for high-level athletes & laborers • Grades IV-VI: CC ligament reconstruction
COMPLICATIONS: AC arthrosis/DJD; stiffness; associated injuries (pneumothorax, fracture, neurapraxia)			

Anterior Dislocation

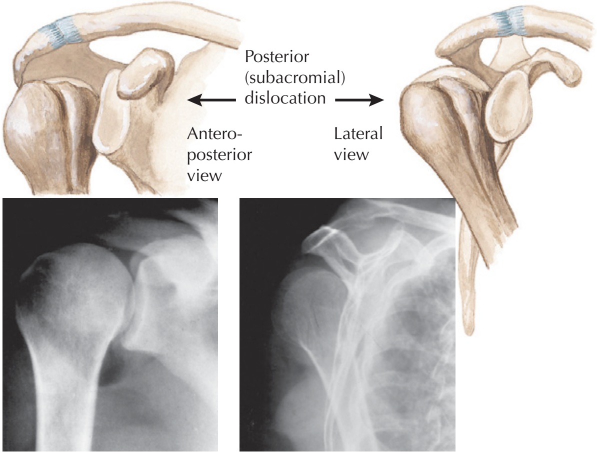


Anterior dislocation (most common)



Anteroposterior radiograph Anterior dislocation

Posterior Dislocation



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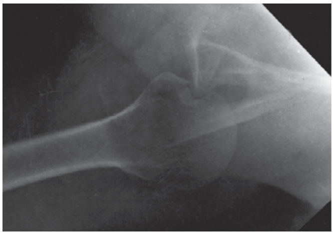
D. Mascaro

Anteroposterior radiograph. Difficult to determine if humeral head within, anterior, or posterior to glenoid cavity.

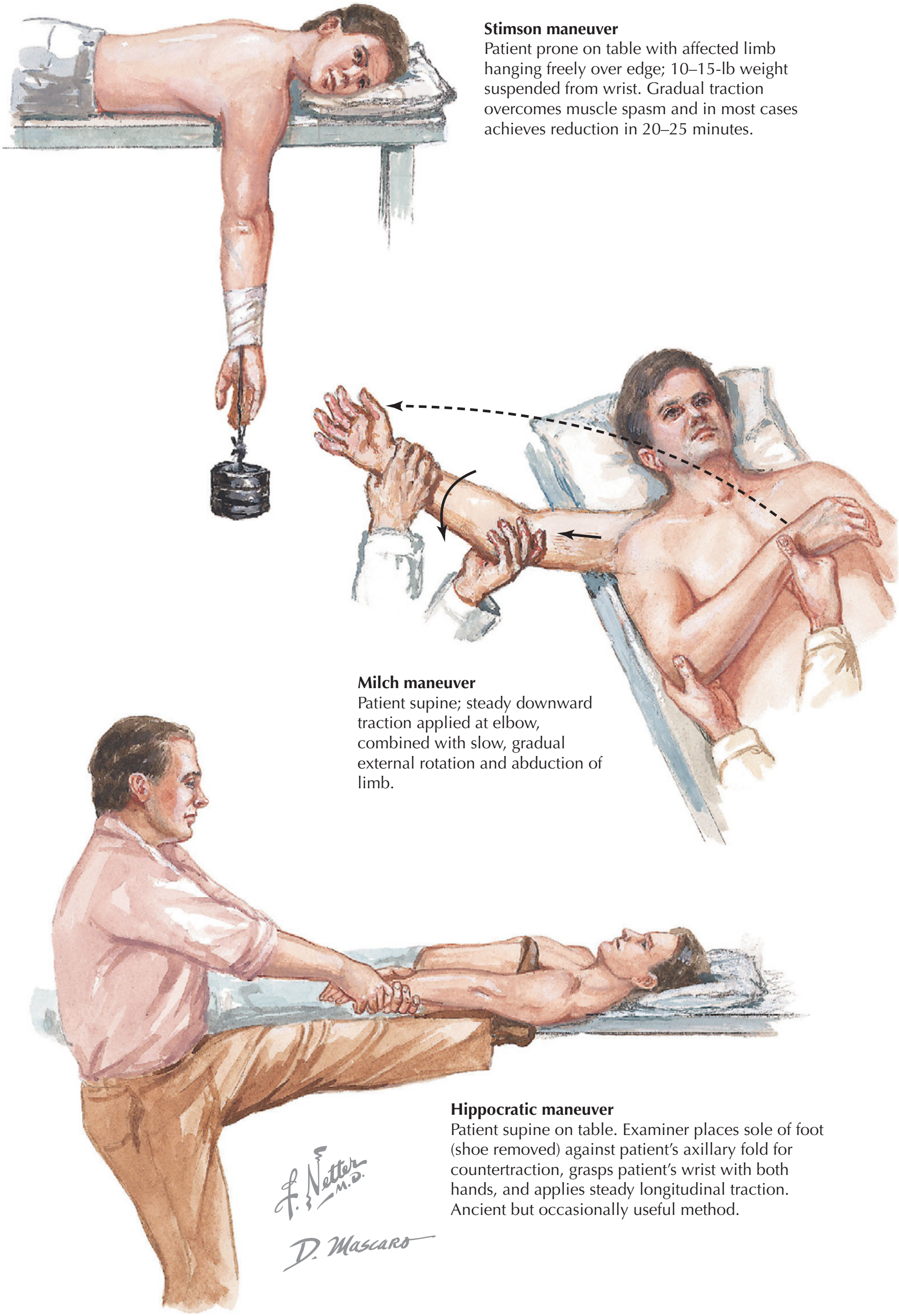
Lateral radiograph (parallel to plane of body of scapula). Humeral head clearly seen to be posterior to glenoid cavity.



True axillary view. Also shows humeral head posterior to glenoid cavity.

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
GLENOHUMERAL DISLOCATION			
• Most common dislocation • Common in young/athletic patients (recurrence >90% if <25y.o.) • Associated w/ labral tears (<40y.o.) and rotator cuff tears (>40y.o.) • Associated with fxs: tuberosity or glenoid rim (“bony Bankart”) • Posterior dislocations associated w/ seizures • Humeral head impression fracture (Hill-Sachs lesion) can occur	**Hx:** Trauma/fall, pain, inability to move arm **PE:** “Flattened” shoulder, no ROM, test axillary nerve function **XR:** 3-view shoulder; must have axillary lateral for posterior dislocation **CT:** To evaluate fxs: tuberosity or glenoid	Anatomic (based on location of humeral head): • Anterior (>90%) • Posterior (often missed) • Inferior (luxatio erecta: abducted arm cannot be lowered [rare]) • Superior (extremely rare)	• Acute: reduce dislocation • Methods (with sedation): ∘ Hippocratic/traction ∘ Stimson ∘ Milch ∘ Scapular retraction • Immobilize: sling for 2wk • Physical therapy • ORIF of displaced fxs • Consider early labral repair in young patients
COMPLICATIONS: Recurrent dislocation/instability (esp. in young/<25y.o.); nerve injury (axillary, musculocutaneous)			

Reduction of Anterior Dislocation of Glenohumeral Joint

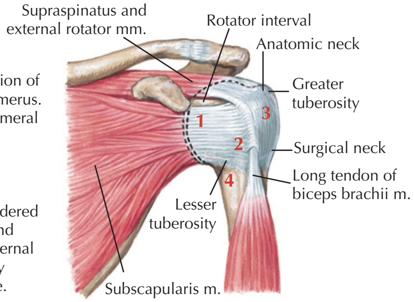


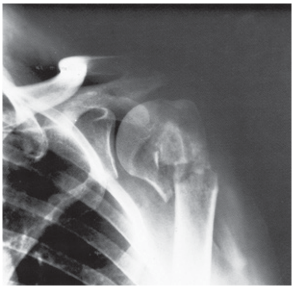
Stimson maneuver
Patient prone on table with affected limb hanging freely over edge; 10–15-lb weight suspended from wrist. Gradual traction overcomes muscle spasm and in most cases achieves reduction in 20–25 minutes.

Milch maneuver
Patient supine; steady downward traction applied at elbow, combined with slow, gradual external rotation and abduction of limb.

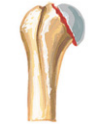
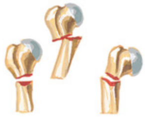
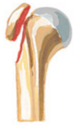
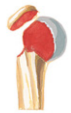
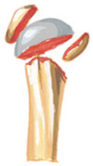
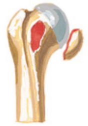
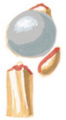
Hippocratic maneuver
Patient supine on table. Examiner places sole of foot (shoe removed) against patient's axillary fold for countertraction, grasps patient's wrist with both hands, and applies steady longitudinal traction. Ancient but occasionally useful method.

Neer four-part classification of fractures of proximal humerus.
1. Articular fragment (humeral head).
2. Lesser tuberosity.
3. Greater tuberosity.
4. Shaft. If no fragments displaced, fracture considered stable (most common) and treated with minimal external immobilization and early range-of-motion exercise.


Supraspinatus and external rotator mm.
Rotator interval
Anatomic neck
Greater tuberosity
Surgical neck
Long tendon of biceps brachii m.
Lesser tuberosity
Subscapularis m.
1
2
3
4

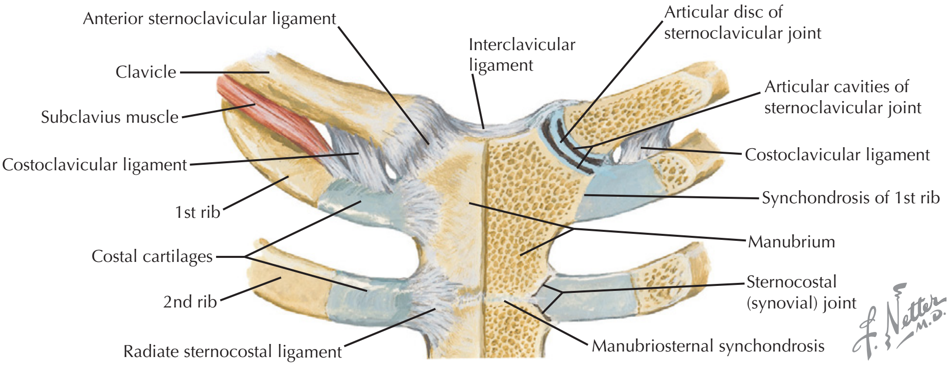


Neer Classification of Proximal Humerus Fractures

2 Part	3 Part	4 Part
Anatomical neck 		
Surgical neck 		
Greater tuberosity 	Greater tuberosity 	Greater and lesser tuberosities 
Lesser tuberosity 	Lesser tuberosity 	

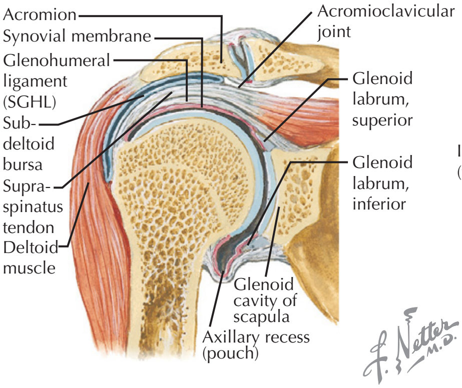
DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
PROXIMAL HUMERUS FRACTURE			
• Common fx, esp. in elderly/osteoporotic patients • Proximal humeral cancellous bone is susceptible to fx • Muscular attachments determine displacement pattern • Most are minimally displaced/1-part fxs • Associated with rotator cuff tears	**Hx:** Trauma/fall, pain, difficult to move arm **PE:** Humeral tenderness, decreased ROM, +/− deformity **XR:** 3-view shoulder **CT:** Identify fragments and displacement	• Neer: based on number of parts (fragments) • Parts (4): head, GT, LT, shaft • Fragment must be >1cm displaced or 45° angulation to be considered a "part" • Multiple combinations of fragments/parts possible	• 1 part: sling, early motion • 2 part: closed reduction & coaptation splint, then PT • 3 part: operative: PCP vs ORIF (locking plate) • 4 part: ORIF vs hemiarthroplasty
COMPLICATIONS: Shoulder stiffness, AVN (anatomic neck fractures), nerve injury (axillary, brachial plexus), nonunion			

Sternoclavicular Joint


Anterior sternoclavicular ligament
Clavicle
Subclavius muscle
Costoclavicular ligament
1st rib
Costal cartilages
2nd rib
Radiate sternocostal ligament
Interclavicular ligament
Articular disc of sternoclavicular joint
Articular cavities of sternoclavicular joint
Costoclavicular ligament
Synchondrosis of 1st rib
Manubrium
Sternocostal (synovial) joint
Manubriosternal synchondrosis

LIGAMENT	ATTACHMENTS	COMMENTS
SHOULDER JOINTS		
General		
• The shoulder is made up of 4 separate articulations. Shoulder motion is a combined movement from all 4 articulations: 1. Sternoclavicular joint, 2. Glenohumeral joint, 3. Acromioclavicular joint, 4. Scapulothoracic articulation • The shoulder joint has the most range of motion in the body. ◦ Forward flexion: 0-170° ◦ Extension: 0-60° ◦ Abduction: 0-170/180° ◦ Internal rotation: to thoracic spine ◦ External rotation: up to 70° • 2:1 ratio of glenohumeral joint to scapulothoracic articulation motion during shoulder abduction • Inherently unstable joint with huge ROM potential. Static and dynamic stabilizers give joint stability. ◦ Static: glenoid, labrum, articular congruity, glenohumeral ligaments & capsule, negative intraarticular pressure ◦ Dynamic: rotator cuff muscles/tendons, biceps tendon, scapular stabilizers (periscapular muscles), proprioception • Shallow glenoid "socket" gives minimal bony stability, but is deepened/stabilized by the fibrocartilaginous labrum. • Labrum serves as a "bumper"/stop to humeral subluxation, as well attachment site for capsuloligamentous structures. Joint instability can result from labral tear/detachment with loss of "bumper" and resultant ligamentous laxity. • Rotator cuff: confluent "horseshoe-" shaped insertion of 4 stabilizing muscle tendons inserting on the proximal humerus (greater & lesser tuberosities). RC muscles actively keep humeral head seated into glenoid during all motions.		
STERNOCLAVICULAR JOINT		
Diarthrodial/double gliding joint. Only true attachment of upper extremity to axial skeleton. ROM: clavicle rotates in joint up to 50° on the fixed sternum.		
Capsule	Surrounds joint	Secondary stabilizer
Sternoclavicular	Medial clavicle to sternum Anterior and posterior ligaments	Primary stabilizer of sternoclavicular joint Posterior stronger, anterior dislocation more common
Costoclavicular	Inferior clavicle to costal cartilage	Strongest sternoclavicular ligament
Interclavicular	Between medial ends of clavicle	Secondary stabilizer
Disc	Intraarticular disc	Fibrocartilage disc within the joint
SCAPULOTHORACIC ARTICULATION		
The articulation is not an actual joint. Scapula slides/rotates along posterior ribs (2-7). Multiple muscles (including serratus anterior and trapezius) are involved. 2:1 ratio of GHJ to scapulothoracic motion during flexion & abduction		

Coronal section through joint


Acromion
Synovial membrane
Glenohumeral ligament (SGHL)
Subdeltoid bursa
Supraspinatus tendon
Deltoid muscle
Acromioclavicular joint
Glenoid labrum, superior
Glenoid labrum, inferior
Glenoid cavity of scapula
Axillary recess (pouch)
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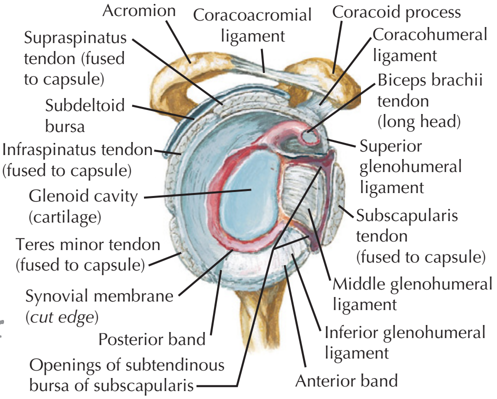
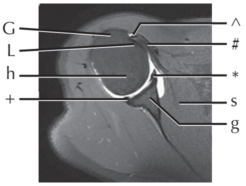
Joint opened: lateral view


Acromion
Coracoacromial ligament
Coracoid process
Coracohumeral ligament
Biceps brachii tendon (long head)
Supraspinatus tendon (fused to capsule)
Subdeltoid bursa
Infraspinatus tendon (fused to capsule)
Glenoid cavity (cartilage)
Teres minor tendon (fused to capsule)
Synovial membrane (cut edge)
Posterior band
Openings of subtendinous bursa of subscapularis
Superior glenohumeral ligament
Subscapularis tendon (fused to capsule)
Middle glenohumeral ligament
Inferior glenohumeral ligament
Anterior band

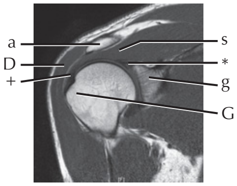
MRI axial, shoulder



Key

G	Greater tuberosity
L	Lesser tuberosity
h	Humeral head
^	Biceps tendon
#	Subscapularis tendon
s	Subscapularis
g	Glenoid
*	Anterior labrum
+	Posterior labrum

MRI coronal, shoulder



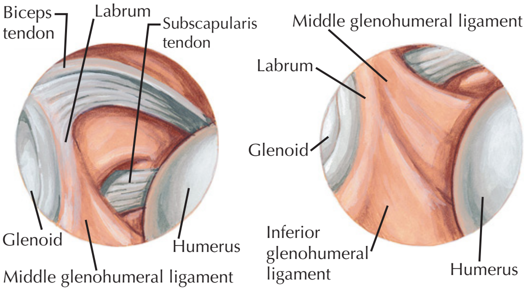
Key

D	Deltoid
s	Supraspinatus
+	Supraspinatus tendon
a	Acromion
G	Greater tuberosity
*	Superior labrum
g	Glenoid

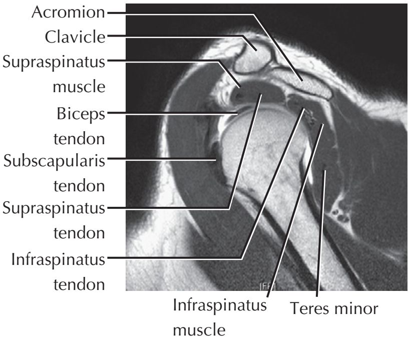
LIGAMENT	ATTACHMENTS	COMMENTS
GLENOHUMERAL JOINT		
Spheroidal ("ball & socket") joint. Inherently unstable joint stabilized by dynamic and static restraints		
Glenohumeral Ligaments		
Superior (SGHL)	Anterosuperior glenoid rim/labrum to proximal lesser tuberosity	Resists inferior translation & ER in shoulder adduction Resists posterior translation in 90° of forward flexion
Middle (MGHL)	Anterosuperior glenoid rim/labrum (inferior to SGHL) to just medial to lesser tuberosity	Resists anteroposterior translation in 45° of abduction Secondary restraint to translation & ER in adduction Buford complex: thickened MGHL & absent anterior/superior labrum
Inferior (IGHL)	Most important ligament, forms sling that tightens in abduction & ER (ant. band)/IR (post. band)	
• Anterior band (AIGHL)	Anterior glenoid/labrum (3 o'clock) to inferior humeral neck	Resists anterior & inferior translation in abduction & ER; must be tightened/"shifted" in anterior instability or MDI
• Posterior band (PIGHL)	Posterior glenoid/labrum (9 o'clock) to inferior humeral neck	Resists posterior translation in IR & 90° flexion
Other		
Coracohumeral (CHL)	Coracoid base to both LT and GT (either side of bicipital groove)	With SGHL, resists inferior translation in adduction; part of pulley to stabilize biceps tendon in joint and groove
Labrum	Circumferentially attached to glenoid	Fibrocartilage: deepens glenoid, provides more contact area, adds stability; insertion site for some GH ligaments
Capsule	Surrounds joint	Maintains intraarticular negative pressure, thin posteriorly

- Glenohumeral ligaments: Discrete thickenings of anterior and inferior capsule that provide stability to the joint. There are no ligaments posteriorly or superiorly.
- Rotator interval: Triangular space between anterior border of supraspinatus and superior border of subscapularis
  - Contents: SGHL, CHL, and biceps tendon, anterosuperior glenohumeral capsule
  - Tightening of this interval can decrease the inferior translation in adduction/"sulcus sign" in the unstable shoulder
- Biceps pulley: SGHL, CHL, subscapularis form an anterior pulley to keep biceps tendon located in joint/bicipital groove

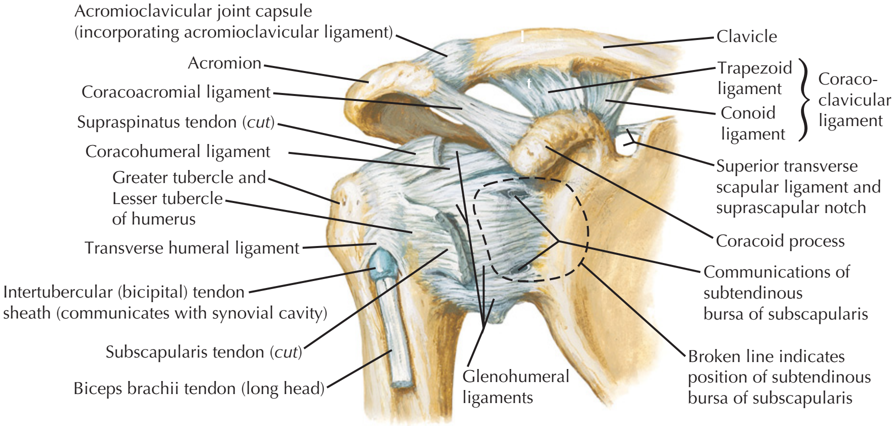
Arthroscopy of Shoulder


Biceps tendon
Labrum
Subscapularis tendon
Glenoid
Humerus
Middle glenohumeral ligament
Middle glenohumeral ligament
Labrum
Glenoid
Inferior glenohumeral ligament
Humerus

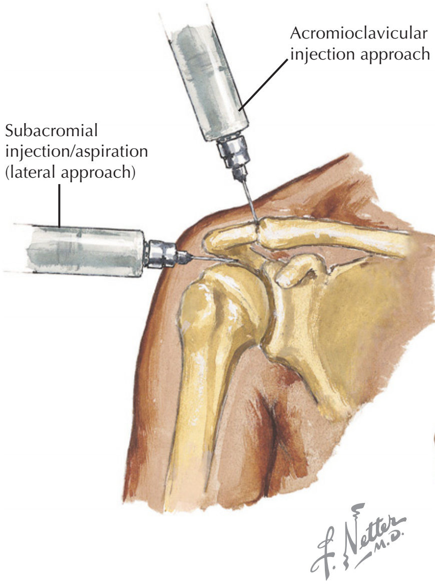
MRI sagittal, shoulder


Acromion
Clavicle
Supraspinatus muscle
Biceps tendon
Subscapularis tendon
Supraspinatus tendon
Infraspinatus tendon
Infraspinatus muscle
Teres minor

Anterior view


Acromioclavicular joint capsule (incorporating acromioclavicular ligament)
Acromion
Coracoacromial ligament
Supraspinatus tendon (*cut*)
Coracohumeral ligament
Greater tubercle and
Lesser tubercle
of humerus
Transverse humeral ligament
Intertubercular (bicipital) tendon sheath (communicates with synovial cavity)
Subscapularis tendon (*cut*)
Biceps brachii tendon (long head)
Glenohumeral ligaments
Clavicle
Trapezoid ligament
Conoid ligament
Coraco-clavicular ligament
Superior transverse scapular ligament and suprascapular notch
Coracoid process
Communications of subtendinous bursa of subscapularis
Broken line indicates position of subtendinous bursa of subscapularis

LIGAMENT	ATTACHMENTS	COMMENTS
ACROMIOCLAVICULAR JOINT		
Diarthrodial (plane/gliding) joint. Very limited motion (5° rotation). Common site of injury and/or painful degeneration.		
Capsule	Surrounds joints	Weak stabilizer, but sufficient under routine loads
Acromioclavicular	Thickening of superior capsule	Provides anterior to posterior stability and axial stability Injured (to some degree) in all AC separations
Coracoclavicular ◦ Conoid ◦ Trapezoid	Coracoid base to inferior clavicle Posteromedial insertion on clavicle Anterolateral insertion on clavicle	Provides vertical stability to the clavicle at the AC joint Stronger resistance to vertical load than trapezoid Resists axial load to shoulder (more oblique fibers)
Disc	In joint, between clavicle & acromion	Interposed to cushion partially incongruent joint
OTHER STRUCTURES		
Coracoacromial	Coracoid tip to anterior and inferior acromion	Key component of the coracoacromial arch; prevents humerus migration in rotator cuff–deficient shoulder
Superior transverse scapular	Crosses suprascapular notch	Suprascapular nerve travels under ligament, suprascapular artery crosses over it.
Transverse humeral	Lesser tuberosity to greater tuberosity (crosses bicipital groove)	Stabilizes biceps tendon within the bicipital groove Lateral aspect of rotator interval


Acromioclavicular injection approach
Subacromial injection/aspiration (lateral approach)
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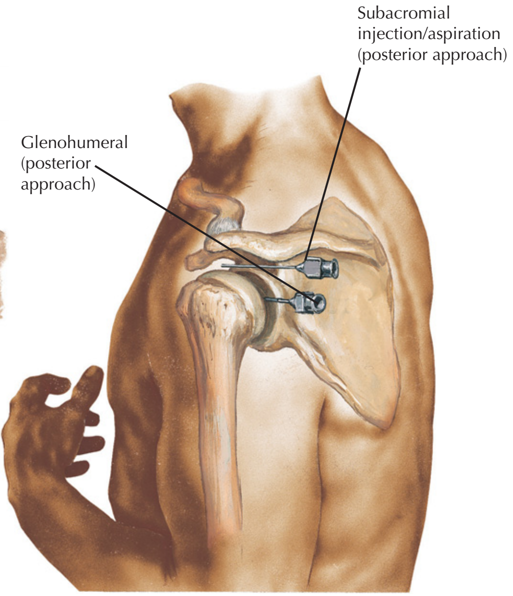

Subacromial injection/aspiration (posterior approach)
Glenohumeral (posterior approach)

STEPS

INJECTION OF ACROMIOCLAVICULAR JOINT

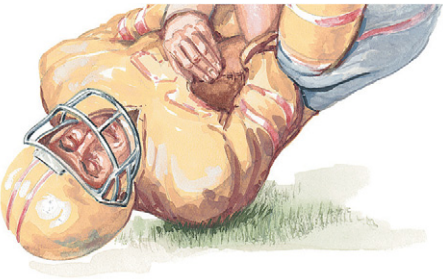
1. Ask patient about allergies
2. Palpate clavicle distally to AC joint (sulcus)
3. Prep skin (iodine/antiseptic soap) over AC joint
4. Anesthetize skin with local (quarter size spot)
5. Use 25g needle, insert needle into sulcus vertically (or with slight lateral to medial tilt) and into joint. You should feel a "pop/give" as the needle enters the joint. Inject 2ml of 1:1 local/corticosteroid preparation (the joint may hold <2ml of fluid). A subcutaneous wheal indicates that the needle tip is superficial to the AC capsule.
6. Dress injection site

INJECTION OF THE SUBACROMIAL SPACE

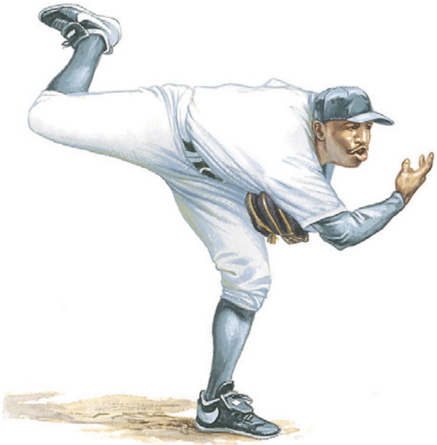
1. Ask patient about allergies
2. Palpate the acromion: define its borders (esp. lateral border & posterolateral corner)
3. Prep skin (iodine/antiseptic soap) over acromial edge
4. Anesthetize skin with local (quarter size spot)
5. Hold finger (sterile glove) on acromion, insert needle under acromion (lateral or posterior) w/ slight cephalad tilt. Aspirate to ensure not in a vessel, then inject 5ml of preparation; will flow easily if in joint. Use: a. diagnostic injection: local only; b. therapeutic injection: local/corticosteroid
6. Dress injection site

GLENOHUMERAL INJECTION

1. Ask patient about allergies
2. Palpate the posterior shoulder for the "soft spot" (usually 2cm down, 1cm medial to posterolateral corner of the acromion). Also palpate the coracoid process on the anterior aspect of the shoulder.
3. Prepare skin (iodine/antiseptic soap) over the "soft spot" on posterior shoulder
4. Anesthetize the skin overlying the "soft spot" (quarter size spot)
5. With sterile gloves, palpate the "soft spot" and the coracoid process. Then insert the needle into the soft spot and aim it toward the coracoid process. If the needle hits bone it should be redirected (glenoid: move lateral; humerus: move medial). Aspirate to ensure not in a vessel. Inject preparation (local +/− corticosteroid) into joint (should flow easily if in the joint space)
6. Dress injection site



Injury to acromioclavicular joint. Usually caused by fall on tip of shoulder, depressing acromion (shoulder separation)



Throwing athletes can develop rotator cuff tears, internal impingement, and motion abnormalities

Shoulder instability is common in swimmers

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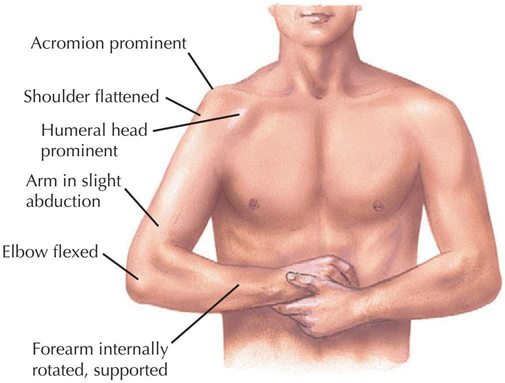
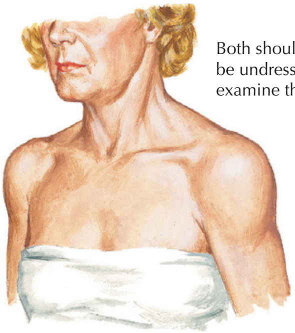
C. Machado M.D.
JOHN A. CRAIG AD
D. Mascaro

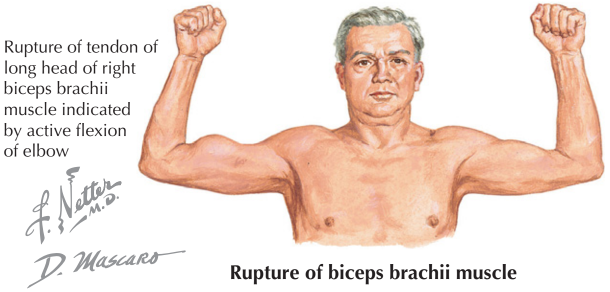
QUESTION	ANSWER	CLINICAL APPLICATION
1. Age	Old	Rotator cuff tear, impingement, arthritis (OA), adhesive capsulitis (frozen shoulder), humerus fracture (after fall)
	Young	Instability, labral tear, AC injury, distal clavicle osteolysis, impingement in athletes
2. Pain		
a. Onset	Acute	Fracture, dislocation, rotator cuff tear, acromioclavicular injury
b. Location	Chronic	Impingement, arthritis/DJD, rotator cuff tear
	On top/AC joint	AC joint arthrosis/separation
c. Occurrence	Night pain	Classic for RC tear, tumor (rare)
d. Exacerbating/ relieving	Overhead worse	Rotator cuff tear, impingement
	Overhead better	Cervical radiculopathy
3. Stiffness	Yes	Osteoarthritis (OA), adhesive capsulitis
4. Instability	“Slips in and out”	Dislocation (>90% anterior, esp. in abduction & ER (e.g., throwing), subluxation, labral tear
5. Trauma	Direct blow	Acromioclavicular (AC) injury
	Fall on outstretched hand	Glenohumeral dislocation (subluxation; fracture)
6. Work/activity	Overhead usage	Rotator cuff tear
	Weight lifting	Osteolysis (distal clavicle)
	Athlete: throwing type	RC tear/impingement (internal), instability (swimmer’s)
	Long-term manual labor	Arthritis (OA)
7. Neurologic sx	Numbness/tingling/”heavy”	Thoracic outlet syndrome, brachial plexus injury
8. PMHx	Cardiopulmonary/GI	Referred pain to shoulder


Acromion prominent
Shoulder flattened
Humeral head prominent
Arm in slight abduction
Elbow flexed
Forearm internally rotated, supported by other hand

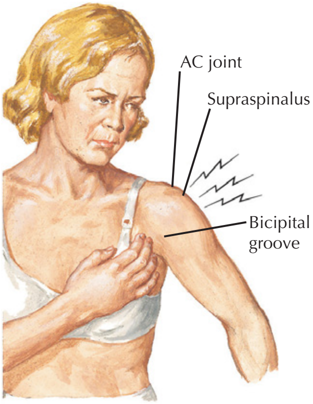
Clinical appearance: glenohumeral dislocation



Both shoulders must be undressed to examine the shoulder.

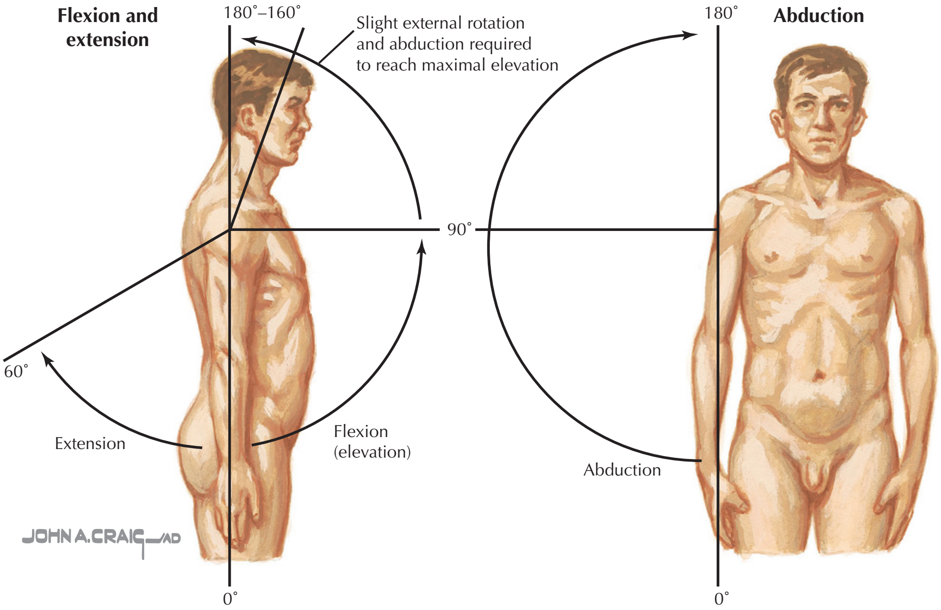

Rupture of tendon of long head of right biceps brachii muscle indicated by active flexion of elbow

Rupture of biceps brachii muscle

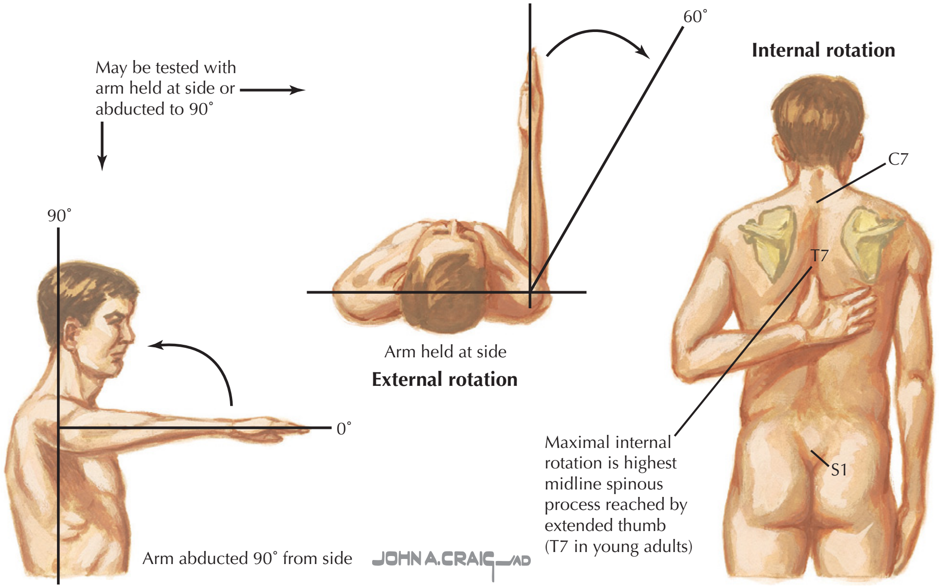

AC joint
Supraspinalus
Bicipital groove

Careful palpation helps isolate the location of the patient's pain.

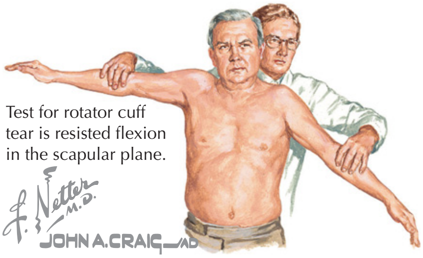
EXAM/OBSERVATION	TECHNIQUE	CLINICAL APPLICATION
INSPECTION		
Both shoulders must be undressed for proper inspection and examination of the shoulder.		
Symmetry	Compare both sides	Acromioclavicular separation, dislocation, muscle atrophy
Wasting	Loss of contour/muscle mass	RC tear, nerve compression (e.g., suprascapular)
Gross deformity	Superior displacement	Acromioclavicular injury (separation)
Gross deformity	Anterior displacement	Anterior dislocation (glenohumeral joint)
Gross deformity	"Popeye" arm	Biceps tendon rupture (usually proximal end of long head)
PALPATION		
AC joint	Feel for end of clavicle	Pain indicates acromioclavicular pathology, instability of distal clavicle, AC separation
Supraspinatus tendon	Feel acromion, down to acromiohumeral sulcus	Pain indicates bursitis and/or supraspinatus tendon (rotator cuff) tear
Greater tuberosity	Prominence on lateral humeral head	Pain indicates rotator cuff tendinitis, tear, or fx
Biceps tendon/bicipital groove	Feel tendon in groove on humerus	Pain indicates biceps tendinitis

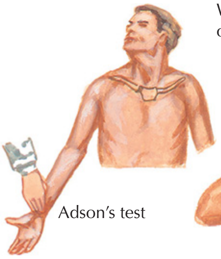

Flexion and extension
180°–160°
Slight external rotation and abduction required to reach maximal elevation
90°
60°
Extension
Flexion (elevation)
0°
JOHN A.CRAIG_AD
180°
Abduction
Abduction
0°

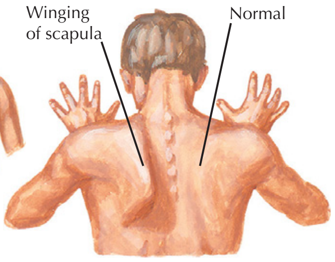
EXAM/OBSERVATION	TECHNIQUE	CLINICAL APPLICATION
RANGE OF MOTION		
Forward flexion	Arms from sides forward	0-160°/180° normal
Extension	Arms from sides backward	0-60° normal
Abduction	Arms from sides outward	0-160°/180 normal
Internal rotation	Reach thumb up back, note level	Mid thoracic (T7) normal, compare sides
External rotation	1. Elbow at side, rotate forearms laterally 2. Abduct arm to 90°, externally rotate up	30-60° normal ER decreased in adhesive capsulitis
• Rotator cuff tear: AROM decreased, PROM ok. Adhesive capsulitis: AROM and PROM are both decreased. • Increased ER may indicate a subscapularis tear		


May be tested with arm held at side or abducted to 90°
90°
0°
Arm abducted 90° from side
60°
Arm held at side
External rotation
Internal rotation
C7
T7
S1
Maximal internal rotation is highest midline spinous process reached by extended thumb (T7 in young adults)
JOHN A.CRAIG_MD

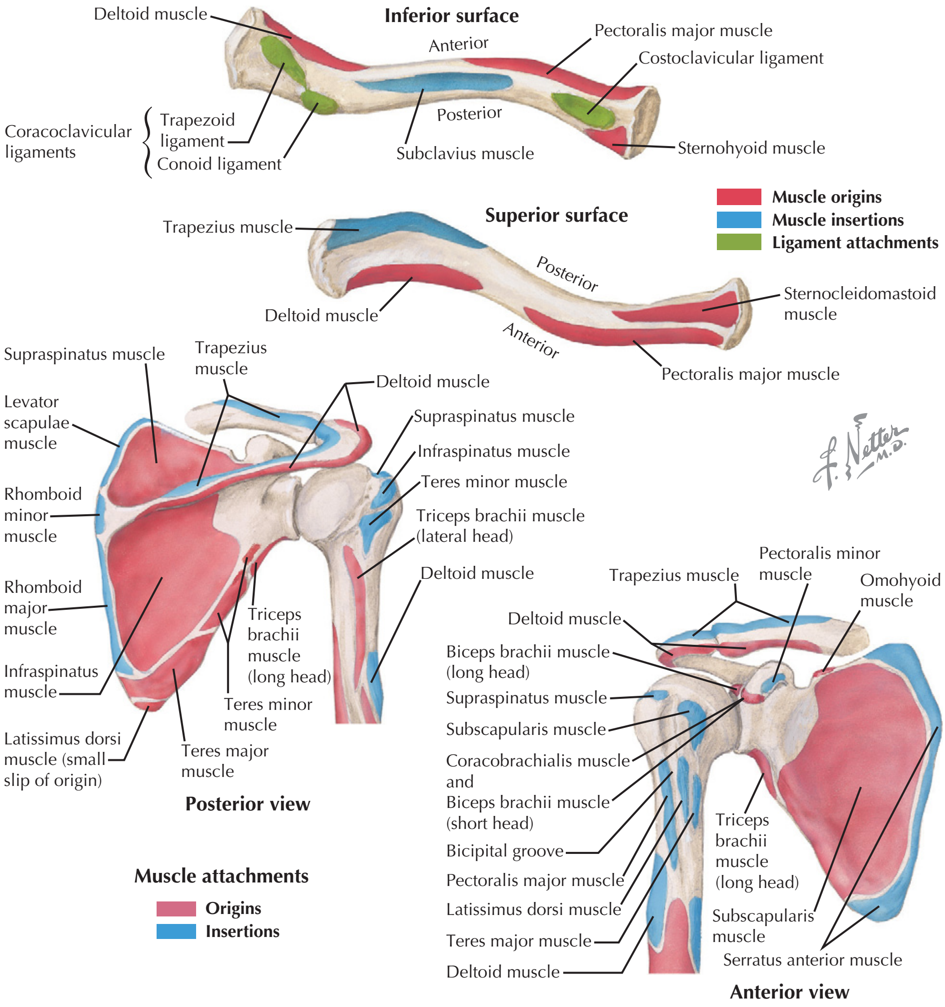
EXAM/OBSERVATION	TECHNIQUE	CLINICAL APPLICATION
NEUROVASCULAR		
Sensory		
Supraclavicular nerve (C4)	Superior shoulder/clavicular area	Deficit indicates corresponding nerve/root lesion
Axillary nerve (C5)	Lateral shoulder	Deficit indicates corresponding nerve/root lesion
T2 segmental nerve	Axilla	Deficit indicates corresponding nerve/root lesion
Motor		
Spinal accessory (CN11)	Resisted shoulder shrug	Weakness = Trapezius or corresponding nerve lesion
Suprascapular (C5-6)	Resisted abduction Resisted external rotation	Weakness = Supraspinatus or nerve/root lesion Weakness = Infraspinatus or nerve/root lesion
Axillary (C5)	Resisted abduction Resisted external rotation	Weakness = Deltoid or corresponding nerve/root lesion Weakness = Teres minor or nerve/root lesion
Dorsal scapular nerve (C5)	Shoulder shrug	Weakness = Levator scapulae/rhomboid or corresponding nerve/root lesion
Thoracodorsal nerve (C7-8)	Resisted adduction	Weakness = Latissimus dorsi or nerve/root lesion
Lateral pectoral nerve (C5-7)	Resisted adduction	Weakness = Pect. major or nerve/root lesion
U/L subscapular nerve (C5-6)	Resisted internal rotation	Weakness = Subscapularis or nerve/root lesion
Long thoracic nerve (C5-7)	Scapular protraction/reach	Weakness = Serratus anterior or nerve/root lesion


Test for rotator cuff tear is resisted flexion in the scapular plane.


Adson's test



EXAM	TECHNIQUE	CLINICAL APPLICATION/DDX
SPECIAL TESTS		
Impingement/Rotator Cuff		
Impingement sign	Forward flexion >90°	Pain indicates impingement syndrome
Hawkins test	FF 90°, then IR	Pain indicates impingement syndrome
Supraspinatus/ Jobe empty can	Pronate arm, resisted FF in scapular plane	Pain or weakness indicates rotator cuff (supraspinatus) tear (partial or full thickness)
Drop arm	FF >90°, try to maintain it	Inability to hold flexion (arm drops) indicates supraspinatus tear
ER lag sign	ER shoulder, patient holds it	Inability to maintain ER indicates infraspinatus tear
Horn blower's	Resisted ER in slight abduction	Weakness indicates rotator cuff tear involving infraspinatus
Lift off	Hand behind back, push backward	Weakness indicates subscapularis tear
Lift off lag sign	Lift hand off back, patient holds it	Inability to hold hand off of low back indicates subscapularis tear
Belly press	Hand on belly, push toward belly	Weakness indicates subscapularis tear
Biceps/Superior Labrum		
Active compression (O'Brien's)	FF 90°, adduct 10°, resisted flexion; in pronation, *then* supination	Pain with resisted flexion, greater in pronation indicates SLAP tear; may also suggest AC joint pathology
Crank	Abduct 90°, axial load, rotate	Pain indicates a SLAP tear
Speed's test	Resisted flexion in scapular plane	Pain indicates biceps lesion or tendinitis
Yergason's test	Elbow 90°, resisted supination	Pain indicates biceps tendinitis
Instability		
Apprehension test	Abduct, externally rotate	Pain or apprehension of indicates anterior instability
Relocation	Abduct, ER, posterior force to arm	Relief of pain/apprehension indicates anterior instability
Load & shift	Axial load, ant/post translation	Increased translation indicates anterior OR posterior instability
Jerk test	Supine, adduct, FF 90°, push posterior	Pain/apprehension/translation indicates posterior instability
Sulcus	Pull down on adducted arm	Sulcus under lateral acromion indicates inferior instability
Other		
X-body adduction	Adduct arm across body	Pain at AC joint indicates AC joint pathology (e.g., arthrosis)
Scapular winging	Push against a wall	Winging of scapula indicates nerve palsy or muscle weakness
Adson's test	Palpate pulse, rotate neck	Numbness or tingling suggestive of thoracic outlet syndrome
Wright's test	Extend arm, rotate neck away	Numbness or tingling suggestive of thoracic outlet syndrome
Spurling's test	Lateral flex/axially compress neck	Reproduction of symptoms indicates cervical neck pathology


Inferior surface
Deltoid muscle
Anterior
Pectoralis major muscle
Costoclavicular ligament
Coracoclavicular ligaments
Trapezoid ligament
Conoid ligament
Posterior
Subclavius muscle
Sternohyoid muscle
Superior surface
Trapezius muscle
Posterior
Deltoid muscle
Anterior
Sternocleidomastoid muscle
Pectoralis major muscle
🟥 Muscle origins
🟦 Muscle insertions
🟩 Ligament attachments
Supraspinatus muscle
Trapezius muscle
Deltoid muscle
Levator scapulae muscle
Supraspinatus muscle
Infraspinatus muscle
Teres minor muscle
Rhomboid minor muscle
Triceps brachii muscle (lateral head)
Deltoid muscle
Rhomboid major muscle
Triceps brachii muscle (long head)
Infraspinatus muscle
Teres minor muscle
Latissimus dorsi muscle (small slip of origin)
Teres major muscle
Posterior view
Muscle attachments
🟥 Origins
🟦 Insertions
Trapezius muscle
Pectoralis minor muscle
Omohyoid muscle
Deltoid muscle
Biceps brachii muscle (long head)
Supraspinatus muscle
Subscapularis muscle
Coracobrachialis muscle and Biceps brachii muscle (short head)
Bicipital groove
Pectoralis major muscle
Latissimus dorsi muscle
Teres major muscle
Deltoid muscle
Triceps brachii muscle (long head)
Subscapularis muscle
Serratus anterior muscle
Anterior view
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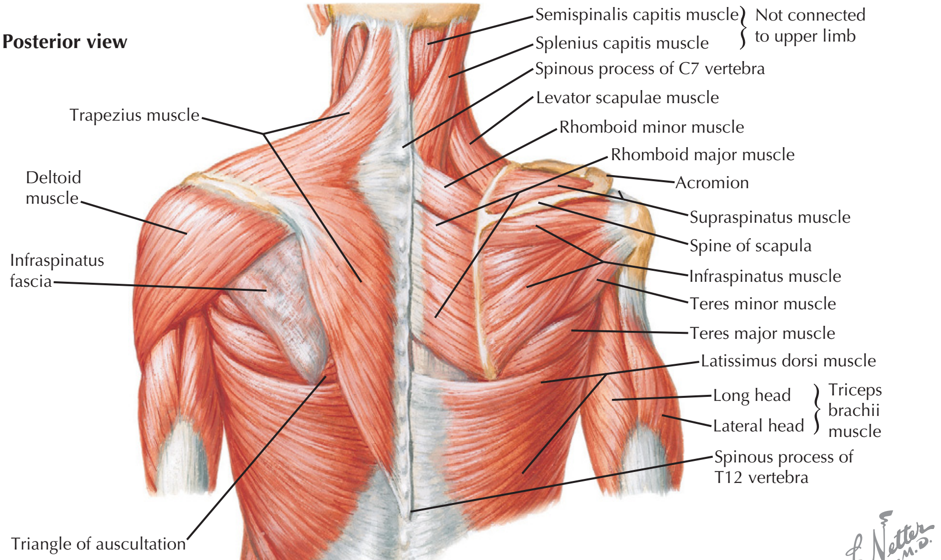
CORACOID PROCESS	GREATER TUBEROSITY	PROXIMAL HUMERUS	SCAPULA (ANTERIOR)	SCAPULA (POSTERIOR)
ORIGINS				
Biceps (SH) Coracobrachialis			Subscapularis Triceps brachii Omohyoid	Supraspinatus Infraspinatus Deltoid (spine/acromion) Teres major & minor Latissimus dorsi
INSERTIONS				
Pectoralis minor	Supraspinatus Infraspinatus Teres minor	Pectoralis major Latissimus dorsi Teres major	Serratus anterior	Trapezius (spine/acromion) Levator scapulae Rhomboid major & minor

- The scapula has 17 muscles that either originate or insert on it.
- Mnemonic for proximal humerus insertions (from lateral to medial): “PLT sandwich” (Pect., Lat., Teres major)

Posterior view


Semispinalis capitis muscle
Splenius capitis muscle
Not connected to upper limb
Spinous process of C7 vertebra
Levator scapulae muscle
Rhomboid minor muscle
Rhomboid major muscle
Trapezius muscle
Deltoid muscle
Acromion
Supraspinatus muscle
Spine of scapula
Infraspinatus fascia
Infraspinatus muscle
Teres minor muscle
Teres major muscle
Latissimus dorsi muscle
Long head
Lateral head
Triceps brachii muscle
Spinous process of T12 vertebra
Triangle of auscultation
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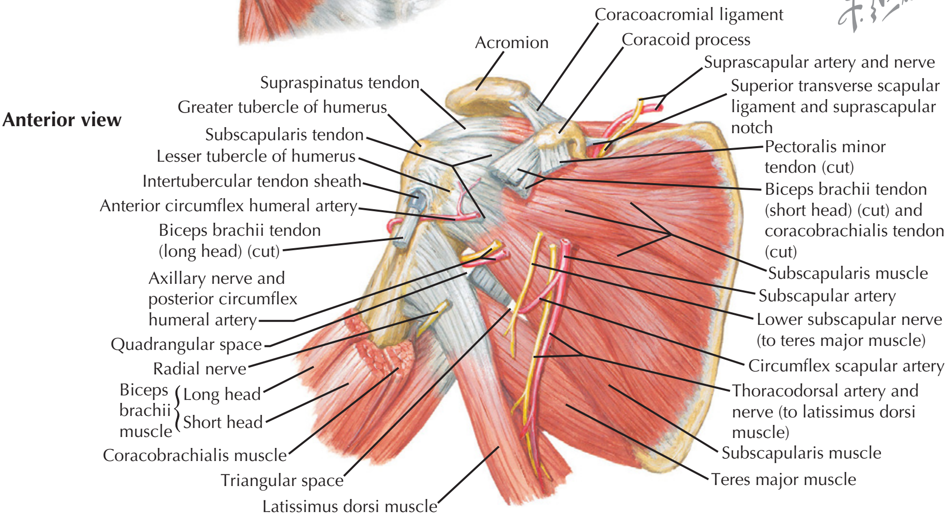
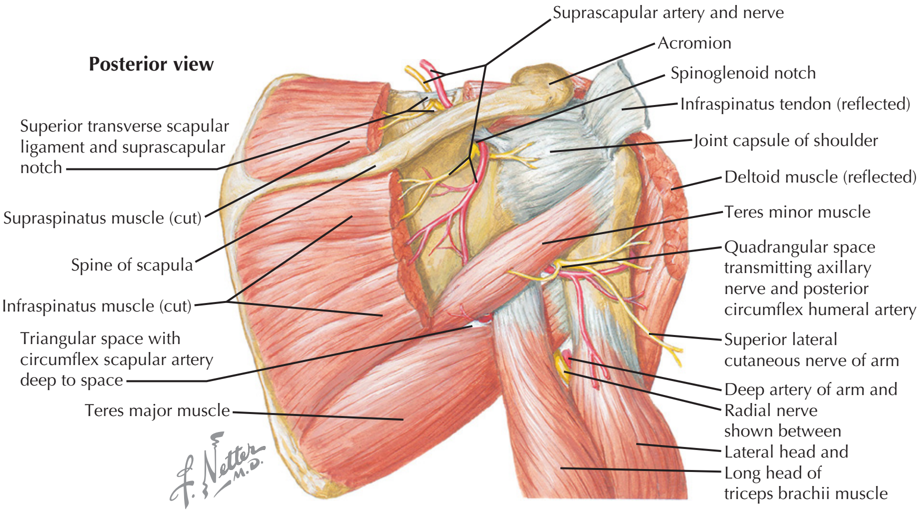
Anterior view

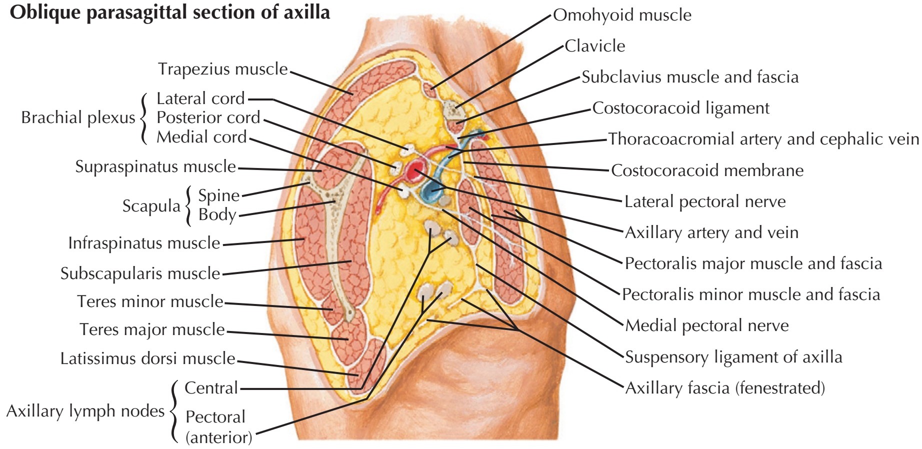

Coracoacromial ligament
Acromion
Coracoid process
Suprascapular artery and nerve
Supraspinatus tendon
Superior transverse scapular ligament and suprascapular notch
Greater tubercle of humerus
Subscapularis tendon
Pectoralis minor tendon (cut)
Lesser tubercle of humerus
Intertubercular tendon sheath
Biceps brachii tendon (short head) (cut) and coracobrachialis tendon (cut)
Anterior circumflex humeral artery
Biceps brachii tendon (long head) (cut)
Subscapularis muscle
Axillary nerve and posterior circumflex humeral artery
Subscapular artery
Lower subscapular nerve (to teres major muscle)
Quadrangular space
Circumflex scapular artery
Radial nerve
Thoracodorsal artery and nerve (to latissimus dorsi muscle)
Biceps brachii muscle
Long head
Short head
Subscapularis muscle
Coracobrachialis muscle
Teres major muscle
Triangular space
Latissimus dorsi muscle

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
Trapezius	C7-T12 spinous process	Clavicle, acromion spine of scapula	Cranial nerve XI	Elevate & rotate scapula	Weakness results in lateral winging
Latissimus dorsi	T7-T12, iliac crest	Humerus (intertubercular groove)	*Thoracodorsal*	Adduct, extend arm, IR humerus	Used for large free flap
Levator scapulae	C1-C4 transverse process	Superior medial scapula	*Dorsal scapular, C3-4*	Elevate scapula	Connects UE to spine
Rhomboid minor	C7-T1 spinous process	Medial scapula (at the spine)	*Dorsal scapular*	Adduct scapula	Connects UE to spine
Rhomboid major	T2-T5 spinous process	Medial scapula	*Dorsal scapular*	Adduct scapula	Connects UE to spine

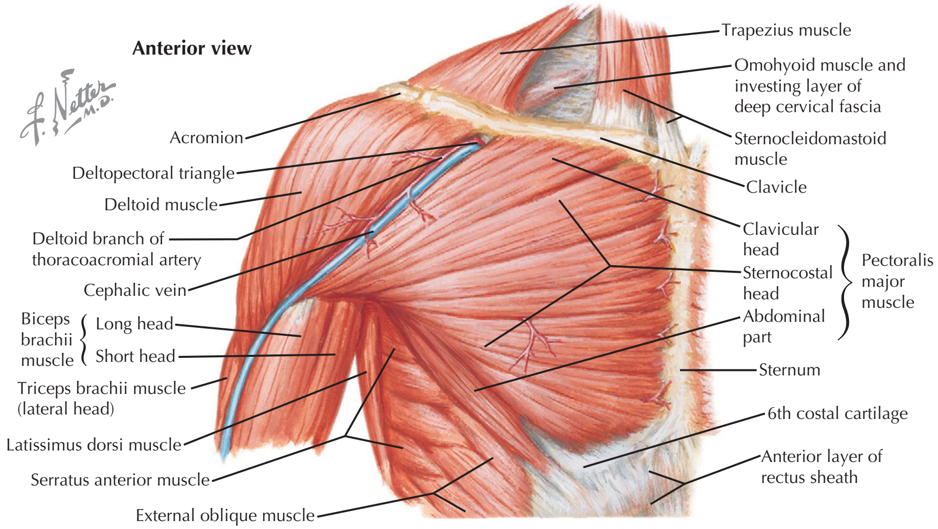

Posterior view
Suprascapular artery and nerve
Acromion
Spinoglenoid notch
Infraspinatus tendon (reflected)
Joint capsule of shoulder
Deltoid muscle (reflected)
Teres minor muscle
Quadrangular space transmitting axillary nerve and posterior circumflex humeral artery
Superior lateral cutaneous nerve of arm
Deep artery of arm and
Radial nerve
shown between
Lateral head and
Long head of
triceps brachii muscle
Superior transverse scapular ligament and suprascapular notch
Supraspinatus muscle (cut)
Spine of scapula
Infraspinatus muscle (cut)
Triangular space with circumflex scapular artery deep to space
Teres major muscle

SPACE/INTERVAL	BORDERS	STRUCTURES
Triangular space	Teres minor Teres major Triceps (long head)	Circumflex scapular artery
Quadrangular space	Teres minor Teres major Triceps (long head) Humerus (medial border)	Axillary nerve Posterior circumflex artery Humeral artery
Triangular interval	Teres major Triceps (long head) Triceps (lateral head)	Radial nerve Deep artery of arm

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
ROTATOR CUFF					
Supraspinatus	Supraspinatus fossa (scapula)	Greater tuberosity (superior)	*Suprascapular*	Abduct FF arm stability	Trapped in impingement, #1 torn rotator cuff tendon
Infraspinatus	Infraspinatus fossa (scapula)	Greater tuberosity (middle)	*Suprascapular*	ER arm, stability	Weak ER: cuff tear or ss nerve lesion in notch
Teres minor	Lateral scapula	Greater tuberosity (inferior)	*Axillary*	ER arm, stability	Rarely torn rotator cuff tendon
Subscapularis	Subscapular fossa (scapula)	Lesser tuberosity	Upper and lower *subscapular*	IR, adduct arm, stability	At risk from anterior approach
OTHER					
Deltoid	Clavicle, acromion spine of scapula	Humerus (deltoid tuberosity)	*Axillary*	Abduct arm	Atrophy: axillary nerve damage
Teres major	Inferior angle of the scapula	Humerus (intertubercular groove)	Low *subscapular*	IR, adduct arm	Protects radial nerve in posterior approach


Oblique parasagittal section of axilla

Trapezius muscle
Brachial plexus
Lateral cord
Posterior cord
Medial cord
Supraspinatus muscle
Scapula
Spine
Body
Infraspinatus muscle
Subscapularis muscle
Teres minor muscle
Teres major muscle
Latissimus dorsi muscle
Axillary lymph nodes
Central
Pectoral (anterior)
Omohyoid muscle
Clavicle
Subclavius muscle and fascia
Costocoracoid ligament
Thoracoacromial artery and cephalic vein
Costocoracoid membrane
Lateral pectoral nerve
Axillary artery and vein
Pectoralis major muscle and fascia
Pectoralis minor muscle and fascia
Medial pectoral nerve
Suspensory ligament of axilla
Axillary fascia (fenestrated)


Anterior view

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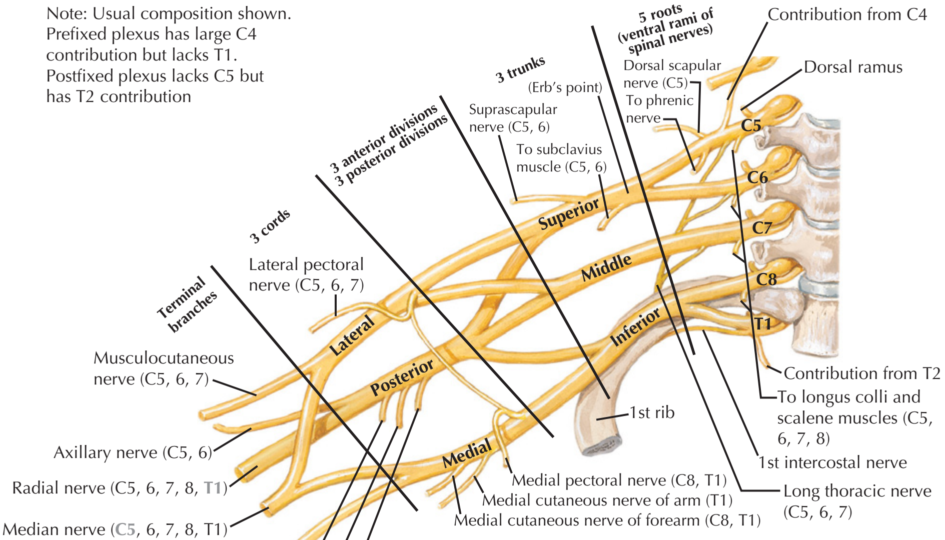
Acromion
Deltopectoral triangle
Deltoid muscle
Deltoid branch of thoracoacromial artery
Cephalic vein
Biceps brachii muscle
Long head
Short head
Triceps brachii muscle (lateral head)
Latissimus dorsi muscle
Serratus anterior muscle
External oblique muscle
Trapezius muscle
Omohyoid muscle and investing layer of deep cervical fascia
Sternocleidomastoid muscle
Clavicle
Clavicular head
Sternocostal head
Abdominal part
Pectoralis major muscle
Sternum
6th costal cartilage
Anterior layer of rectus sheath

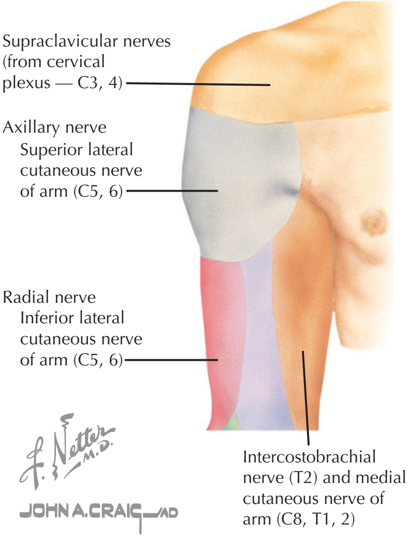
MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
Deltoid	Clavicle, acromion spine of scapula	Humerus (deltoid tuberosity)	*Axillary*	Abducts arm	Atrophy: axillary nerve damage
Pectoralis major	1. Clavicle 2. Sternal	Humerus (intertubercular groove)	Lateral *pectoral* Medial *pectoral*	Adducts arm, IR humerus	Can rupture during weight lifting
Pectoralis minor	Ribs 3-5	Coracoid process (scapula)	Medial *pectoral*	Stabilizes scapula	Divides axillary artery into 3 parts
Serratus anterior	Ribs 1-8 (lateral)	Scapula (anteromedial border)	Long *thoracic*	Holds scapula to chest wall	Paralysis results in medial winging
Subclavius	Rib 1 (and costal cartilage)	Clavicle (inferior border/mid 3rd)	Nerve to subclavius	Depresses clavicle	Cushions subclavian vessels


3 trunks
(Erb's point)
5 roots (ventral rami of spinal nerves)
Contribution from C4
Dorsal ramus
Dorsal scapular nerve (C5)
To phrenic nerve
Suprascapular nerve (C5, 6)
To subclavius muscle (C5, 6)
3 anterior divisions
3 posterior divisions
3 cords
Terminal branches
Lateral pectoral nerve (C5, 6, 7)
Superior
Middle
Inferior
Lateral
Posterior
Medial
C5
C6
C7
C8
T1
Musculocutaneous nerve (C5, 6, 7)
Axillary nerve (C5, 6)
Radial nerve (C5, 6, 7, 8, T1)
Median nerve (C5, 6, 7, 8, T1)
Ulnar nerve (C7, 8, T1)
Lower subscapular nerve (C5, 6)
Thoracodorsal (middle subscapular) nerve (C6, 7, 8)
Upper subscapular nerve (C5, 6)
1st rib
Contribution from T2
To longus colli and scalene muscles (C5, 6, 7, 8)
1st intercostal nerve
Long thoracic nerve (C5, 6, 7)
Medial pectoral nerve (C8, T1)
Medial cutaneous nerve of arm (T1)
Medial cutaneous nerve of forearm (C8, T1)

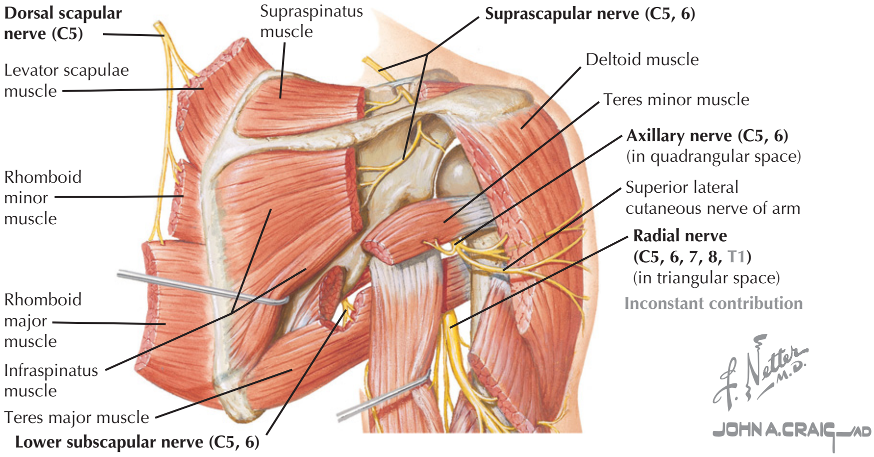
Note: Usual composition shown. Prefixed plexus has large C4 contribution but lacks T1. Postfixed plexus lacks C5 but has T2 contribution

Inconstant contribution

Anterior (palmar) view


Supraclavicular nerves (from cervical plexus — C3, 4)
Axillary nerve
Superior lateral cutaneous nerve of arm (C5, 6)
Radial nerve
Inferior lateral cutaneous nerve of arm (C5, 6)
Intercostobrachial nerve (T2) and medial cutaneous nerve of arm (C8, T1, 2)
F. Netter M.D.
JOHN A.CRAIG_AD

CRANIAL NERVES
Spinal Accessory (CN 11): Runs on levator scapulae *Sensory:* None *Motor:* Trapezius Sternocleidomastoid
CERVICAL PLEXUS
Supraclavicular (C2-3): 3 parts: anterior, middle, posterior *Sensory:* Over trapezius, clavicle, deltoid (superior shoulder) *Motor:* None
BRACHIAL PLEXUS
Roots
Dorsal *Scapular* (C3-5): Pierces middle scalene, is deep to levator scapulae. *Sensory:* None *Motor:* Levator scapulae Rhomboid major & minor
Long *Thoracic* (C5-7): Runs on anterior surface of serratus anterior with the lateral *thoracic* artery. *Sensory:* None *Motor:* Serratus anterior
Upper Trunk
Suprascapular (C5-6): Under the ligament in suprascapular notch, innervates supraspinatus, then through the spinoglenoid notch (where it can be compressed) to infraspinatus fossa (innervates infraspinatus) *Sensory:* Shoulder joint capsule *Motor:* Supraspinatus Infraspinatus
Nerve to Subclavius (C5-6): Descends posterior to clavicle *Sensory:* None *Motor:* Subclavius


Dorsal scapular nerve (C5)
Levator scapulae muscle
Rhomboid minor muscle
Rhomboid major muscle
Infraspinatus muscle
Teres major muscle
Lower subscapular nerve (C5, 6)
Supraspinatus muscle
Suprascapular nerve (C5, 6)
Deltoid muscle
Teres minor muscle
Axillary nerve (C5, 6) (in quadrangular space)
Superior lateral cutaneous nerve of arm
Radial nerve (C5, 6, 7, 8, T1) (in triangular space)
Inconstant contribution
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JOHN A.CRAIG AD

BRACHIAL PLEXUS

Lateral Cord

Lateral *Pectoral* (C5-7): Named for the cord, runs medial to the medial *pectoral* nerve with the *pectoral* artery.

Sensory: None
Motor: Pectoralis major (clavicular portion)
Pectoralis minor (via a branch to the medial *pectoral* n.)

Lateral root to median nerve

Medial Cord

Medial *Pectoral* (C5-7): Named for cord, is lateral to the lateral *pectoral* nerve

Sensory: None
Motor: Pectoralis minor
Pectoralis major (sternal portion)

Medial root to median nerve

Posterior Cord

Upper *Subscapular* (C5-6)

Sensory: None
Motor: Upper subscapularis

Thoracodorsal (C7-8): Runs with *thoracodorsal* artery deep to latissimus dorsi muscle

Sensory: None
Motor: Latissimus dorsi

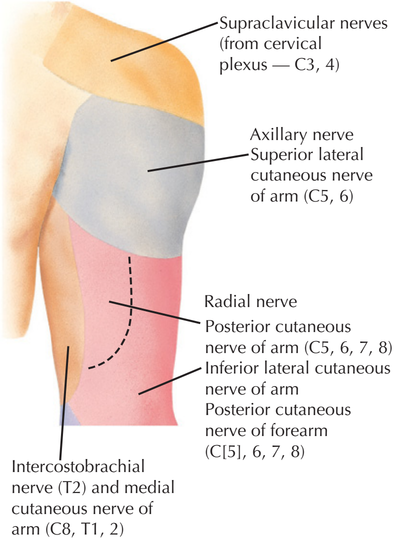
Lower *Subscapular* (C5-6)

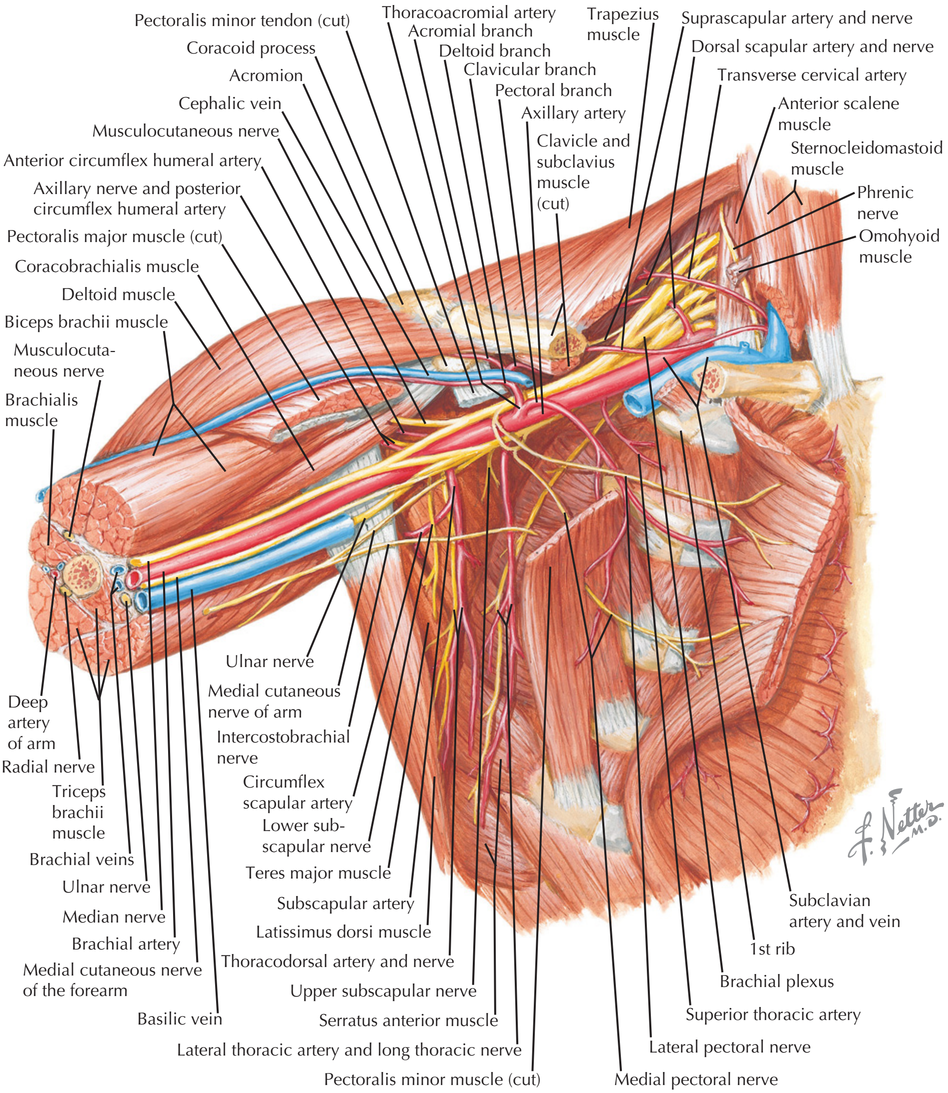
Sensory: None
Motor: Lower subscapularis
Teres major

Axillary (C5-6): Directly inferior to joint capsule, it travels posteriorly with post. circumflex humeral art. thru quadrangular space, then bends anteriorly approx. 5cm distal to acromion. It can be injured in glenohumeral dislocations and lateral approaches.

Sensory: Lateral proximal arm: via **superior lateral cutaneous** n.
Motor: Deltoid: via **deep branch**
Teres minor: via **superficial branch**

Posterior (dorsal) view

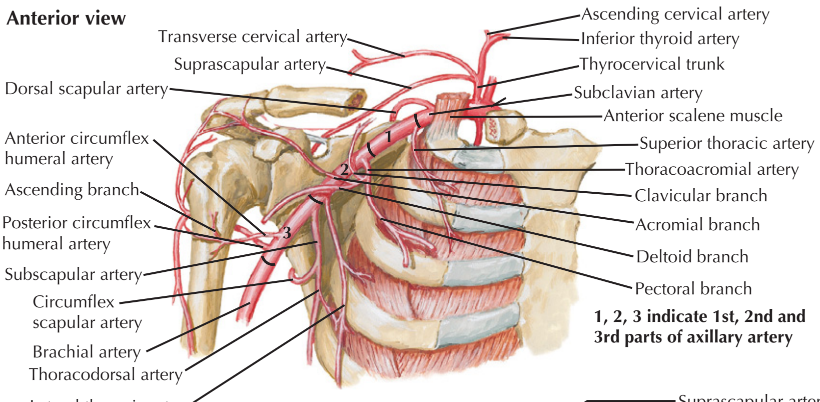

Supraclavicular nerves (from cervical plexus — C3, 4)
Axillary nerve
Superior lateral cutaneous nerve of arm (C5, 6)
Radial nerve
Posterior cutaneous nerve of arm (C5, 6, 7, 8)
Inferior lateral cutaneous nerve of arm
Posterior cutaneous nerve of forearm (C[5], 6, 7, 8)
Intercostobrachial nerve (T2) and medial cutaneous nerve of arm (C8, T1, 2)

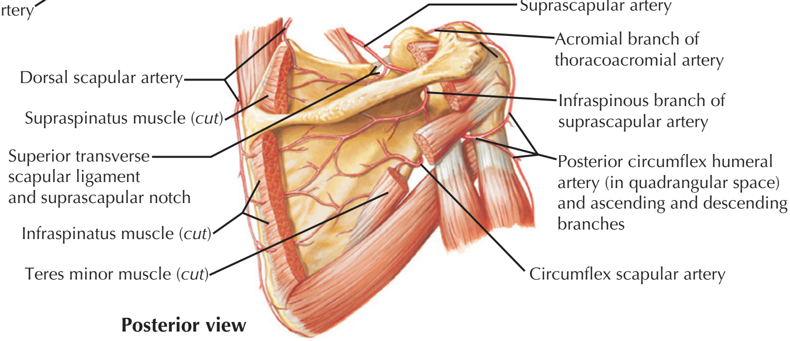

Pectoralis minor tendon (cut)
Coracoid process
Acromion
Cephalic vein
Musculocutaneous nerve
Anterior circumflex humeral artery
Axillary nerve and posterior circumflex humeral artery
Pectoralis major muscle (cut)
Coracobrachialis muscle
Deltoid muscle
Biceps brachii muscle
Musculocutaneous nerve
Brachialis muscle
Thoracoacromial artery
Acromial branch
Deltoid branch
Clavicular branch
Pectoral branch
Axillary artery
Clavicle and subclavius muscle (cut)
Trapezius muscle
Suprascapular artery and nerve
Dorsal scapular artery and nerve
Transverse cervical artery
Anterior scalene muscle
Sternocleidomastoid muscle
Phrenic nerve
Omohyoid muscle
Deep artery of arm
Radial nerve
Triceps brachii muscle
Brachial veins
Ulnar nerve
Median nerve
Brachial artery
Medial cutaneous nerve of the forearm
Basilic vein
Ulnar nerve
Medial cutaneous nerve of arm
Intercostobrachial nerve
Circumflex scapular artery
Lower subscapular nerve
Teres major muscle
Subscapular artery
Latissimus dorsi muscle
Thoracodorsal artery and nerve
Upper subscapular nerve
Serratus anterior muscle
Lateral thoracic artery and long thoracic nerve
Pectoralis minor muscle (cut)
Subclavian artery and vein
1st rib
Brachial plexus
Superior thoracic artery
Lateral pectoral nerve
Medial pectoral nerve
F. Netter M.D.

BRACHIAL PLEXUS

- Brachial ("arm") plexus ("network") is a complex of intertwined nerves that innervate the shoulder and upper extremity.
- It is derived from the ventral rami from C5-T1 (variations: C4 [prefixed], T2 [post-fixed]).
- Subdivisions: rami (roots), trunks, divisions, cords, branches (mnemonic: **R**ob **T**aylor **D**rinks **C**old **B**eer)
- Rami exit between the anterior and medial scalene muscles & travel with the subclavian artery in the axillary sheath.
- The rami and trunks are supraclavicular. There are 2 nerves from the rami, and 2 nerves from the trunks (upper)
- The divisions are under (posterior to) the clavicle. Anterior divisions innervate flexors. Posteriors innervate extensors.
- The cords and branches are infraclavicular. The cords are named for their relationship with the axillary artery.
- Terminal branches of the cords are peripheral nerves to the shoulder region and upper extremity.
- Injury to the plexus can be partial or complete. Injuries affect all nerves distal to the injury (e.g., Erb's palsy: C5-6).

Anterior view

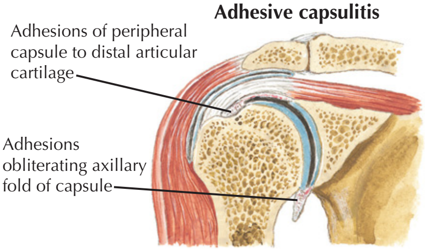

Transverse cervical artery
Suprascapular artery
Dorsal scapular artery
Anterior circumflex humeral artery
Ascending branch
Posterior circumflex humeral artery
Subscapular artery
Circumflex scapular artery
Brachial artery
Thoracodorsal artery
Lateral thoracic artery
Ascending cervical artery
Inferior thyroid artery
Thyrocervical trunk
Subclavian artery
Anterior scalene muscle
Superior thoracic artery
Thoracoacromial artery
Clavicular branch
Acromial branch
Deltoid branch
Pectoral branch
1
2
3
1, 2, 3 indicate 1st, 2nd and 3rd parts of axillary artery


Suprascapular artery
Acromial branch of thoracoacromial artery
Infraspinous branch of suprascapular artery
Posterior circumflex humeral artery (in quadrangular space) and ascending and descending branches
Circumflex scapular artery
Dorsal scapular artery
Supraspinatus muscle (*cut*)
Superior transverse scapular ligament and suprascapular notch
Infraspinatus muscle (*cut*)
Teres minor muscle (*cut*)

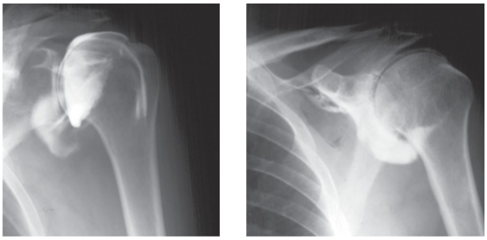
Posterior view

COURSE	BRANCHES	COMMENT/SUPPLY
SUBCLAVIAN ARTERY		
Branches off aorta (L) or brachiocephalic trunk (R), b/w anterior & middle scalene muscles with the brachial plexus	Thyrocervical trunk	3 other branches into the neck
	Suprascapular artery	Runs over the transverse scapular ligament to rotator cuff muscles
	Infraspinatus branch	Runs around spinoglenoid notch with suprascapular n.
	Dorsal scapular	Divides around the levator scapulae muscle
AXILLARY ARTERY		
Continuation of subclavian after the 1st rib. Runs through the axilla into the arm, becoming the brachial artery at the lower border of the teres major muscle	I. Superior thoracic	To serratus anterior and pectoralis muscles
	II. Thoracoacromial	Has 4 branches
	Clavicular branch	Can be injured in clavicle fractures or surgery
	Acromial branch	With CA ligament, at risk in subacromial decompression
	Deltoid branch	With cephalic vein, at risk in deltopectoral approach
	Pectoral branch	Runs with lateral *pectoral* nerve
	Lateral *thoracic*	Runs with long thoracic nerve to serratus anterior
	III. Subscapular	Has 2 main branches
	Circumflex scapular	Seen posteriorly in triangular space
	Thoracodorsal	Runs w/*thoracodorsal* nerve. Used for free flap
	Anterior circumflex humeral	Primary supply of humeral head (via ascending br.)
	Ascending branch	Injury (e.g., anatomic neck fx) leads to osteonecrosis
	Arcuate artery	Supplies most of humeral head, also tuberosities
	Posterior circumflex humeral	Seen in quadrangular space with axillary nerve
The axillary artery is divided into 3 parts by the borders of the pectoralis minor muscle (1st prox., 2nd behind, 3rd distal). The first part (I) has 1 branch, 2nd part (II) has 2 branches, 3rd part (III) has 3 branches.		

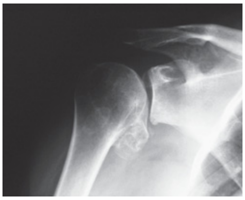
Adhesive capsulitis


Adhesions of peripheral capsule to distal articular cartilage
Adhesions obliterating axillary fold of capsule

Coronal section of shoulder shows adhesions between capsule and periphery of humeral head



Anteroposterior arthrogram of normal shoulder (left). Axillary fold and biceps brachii sheath visualized. Volume of capsule normal. Anteroposterior arthrogram of frozen shoulder (right). Joint capacity reduced. Axillary fold and biceps brachii sheath not evident.



AP radiograph of shoulder demonstrates typical changes of osteoarthritis of the shoulder with narrowing of the joints and prominent osteophyte formation at the inferior aspect of the humeral head.

Glenohumeral arthritis

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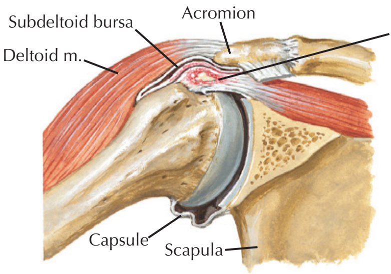
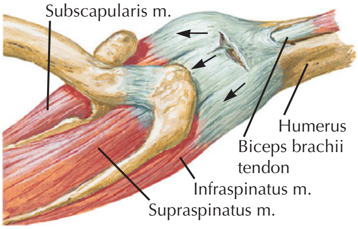
DESCRIPTION	Hx & PE	WORKUP	TREATMENT
ADHESIVE CAPSULITIS ("FROZEN SHOULDER")			
• Synovial inflammation leads to capsular fibrosis (thickening) & loss of joint space (esp. pouch) • Three stages: pain, stiffness, resolving/"thawing"	**Hx:** Pain, stiffness, +/– PMHx (DM, thyroid dz), trauma, immobilization **PE:** Decreased active AND passive ROM	**XR:** Shoulder series: usually normal **Arthrogram:** shows decreased capsular volume	• Physical therapy (gentle active and passive ROM) and pain management (6+ months) • Arthroscopic lysis of adhesions in refractory cases
ACROMIOCLAVICULAR ARTHROSIS			
• Degeneration of the AC joint • Associated with previous trauma, overuse, rotator cuff disease • Osteolysis in weight-lifters	**Hx:** Pain, +/– grinding **PE:** ACJ TTP, crossbody adduction pain, +/– subtle instability (on palpation)	**XR:** AC narrowing/spurs **MR:** Often not needed; will show edema & degeneration	• Rest, activity modification • Corticosteroid injection • Open vs arthroscopic distal clavicle resection (Mumford)
ARTHRITIS (GLENOHUMERAL)			
• Osteoarthritis #1, also RA • Can be posttraumatic (e.g., fx), 2° to RC tear, or 2° to surgery (e.g., Puddi-Platt)	**Hx:** Usually elderly, pain, stiffness, +/– old trauma **PE:** Decreased ROM, +/– wasting, crepitus	**XR:** Joint narrowing, osteophytes **MR:** For rotator cuff evaluation if indicated	• NSAIDs, physical therapy • Corticosteroid injections • Hemi vs total shoulder arthroplasty
BICEPS TENDINITIS			
• Assoc. w/impingement, RC tear (esp. subscapularis), & tendon subluxation (biceps pulley injury)	**Hx:** Pain, +/– snapping **PE:** Biceps TTP, +Speed & Yergason tests	**XR:** Often normal **MR:** Evaluate for tear	• Physical therapy • Corticosteroid injection • Tenodesis vs tenotomy
BICEPS TENDON RUPTURE (PROXIMAL)			
• Usually in older population • Often degenerative tear • Associated with impingement & RC tears	**Hx:** Pain & deformity **PE:** "Popeye" arm deformity, weak supination	**XR:** Usually normal **MR:** Often not needed, but will show tear	• Physical therapy. Patient often has residual weakness in supination • Consider tenodesis (esp. in younger/active patients)

External impingement

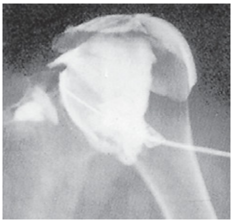


Abduction of arm causes repeated impingement of greater tubercle of humerus on acromion, leading to degeneration and inflammation of supraspinatus tendon, secondary inflammation of bursa, and pain on abduction of arm. Calcific deposit in degenerated tendon produces elevation that further aggravates inflammation and pain.

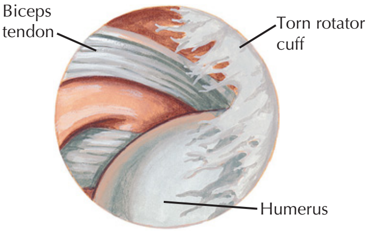
Rotator cuff tear

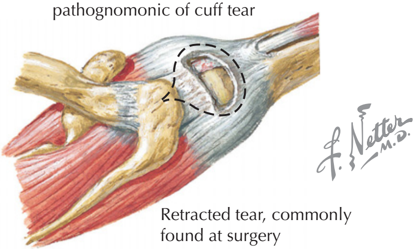


Acute rupture (superior view). Often associated with splitting tear parallel to tendon fibers.



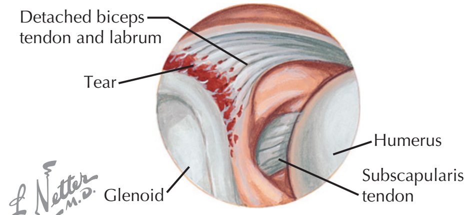
Communication between shoulder joint and subdeltoid bursa is pathognomonic of cuff tear



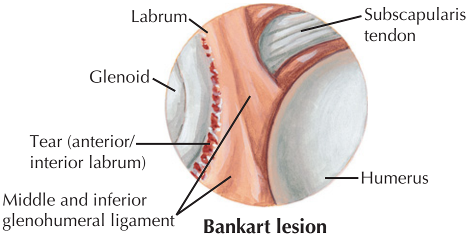


Retracted tear, commonly found at surgery

DESCRIPTION	Hx & PE	WORK-UP	TREATMENT
EXTERNAL (OUTLET) IMPINGEMENT			
• Rotator cuff & bursa trapped b/w acromion & greater tuberosity • Spectrum of disease from bursitis to tendinopathy to partial- to full-thickness RC tear	**Hx:** Pain w/ overhead activities, lifting, etc. **PE:** +Neer sign/test, +Hawkins test. RC: strong +/– painful	**XR:** Outlet view: look for hooked (type 2, 3) acromion or spur **MR:** Best study to evaluate for possible RC tear	• NSAIDs, activity modification • Physical therapy (rotator cuff strengthening) • Subacromial steroid injection • Subacromial decompression
ROTATOR CUFF TEAR			
• Chronic: associated w/impingement (usu. on bursal side) • Acute: in throwers (articular side) or after dislocation (> 40y.o.) • Supraspinatus #1 • Graded by size: <3cm, 3-5cm, >5cm or # of tendons involved	**Hx:** Pain overhead & at night, +/– weakness **PE:** Pain +/– weakness: ◦ SS: FF, + empty can ◦ IS: ER, + hornblower's ◦ Subscap: IR, + lift off, + belly press, incr. ER	**XR:** May show Ca^{++} of tendon, spurs, or humeral head elevation **MR:** Excellent for cuff tear imaging; contrast shows communication b/w joint & subacromial space	• Activity modification, NSAIDs • PT: ROM, RC strengthening, scapular stabilization • Operative ◦ Partial tear: SA decompression and cuff debridement vs repair ◦ Full tear: RC repair



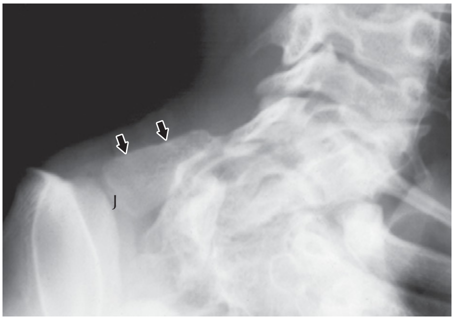
Type II slap lesion


Labrum
Subscapularis tendon
Glenoid
Tear (anterior/interior labrum)
Humerus
Middle and inferior glenohumeral ligament

Bankart lesion

DESCRIPTION	Hx & PE	WORK-UP	TREATMENT
GLENOHUMERAL INSTABILITY			
"TUBS"			
• Result of a dislocation (**T**rauma) • Most often **U**nilateral • Labral tear (**B**ankart lesion) results from the dislocation • **S**urgery is most often indicated (due to 90% recurrence rate)	**Hx:** Dislocation, pain, & recurrent instability **PE:** + apprehension & relocation, + load & shift (one direction), + jerk (posterior lesion)	**XR:** West point view **CT:** For glenoid lesions **MR Arthrogram:** Sensitive for labral tear; may show increased capsular volume	• Physical therapy (rotator cuff strengthening) & ROM • Bankart (labral) repair with capsular imbrication (open or arthroscopically)
"AMBRI"			
• **A**traumatic (no dislocation) • **M**ultidirectional (ant, inf, post) • **B**ilateral (1 side often worse) • Responds to **R**ehabilitation • **I**nferior capsular shift may help	**Hx:** Pain (from increased joint mobility) **PE:**+ load & shift (usu. both ant. & post.), + sulcus sign	**XR:** Often normal **MR:** Often not needed in absence of trauma; labrum normal in AMBRI	• Extended physical therapy (rotator cuff strengthening) • Open inferior capsular shift vs arthroscopic capsular (up to 270°) imbrication
PECTORALIS MAJOR RUPTURE			
• Rare injury, usu. young patients • Most common in weight-lifters • Maximal eccentric contraction	**Hx:** Acute pain **PE:** Axilla deformity, accentuated with adduction	**XR:** Look for avulsion **MR:** Can evaluate for tendon retraction	• Early repair indicated • Late repair controversial • Nonoperative treatment yields adequate results
SCAPULAR WINGING			
• Medial: serratus anterior weakness 2° long thoracic nerve palsy • Lateral: trapezius weakness 2° spinal accessory (CN11) palsy	**Hx:** Weakness **PE:** Winging of scapula observed from back	**XR:** Usually normal **EMG/NCS:** Confirm nerve palsy	• Observation (1-2 years) • Refractory cases: Medial: pect. major transfer Lateral: levator scapulae transfer
SUPERIOR LABRAL TEAR (SLAP LESION)			
• Tear of **s**uperior **l**abrum (biceps anchor) from **a**nt. to **p**ost. • Chronic (with RCT) or acute (load on outstretched arm) • 7 types based on extent of tear	**Hx:** Pain +/– popping, weakness, etc **PE:** + O'Brien's test, + crank test, +/– painful arc of motion	**XR:** Usually normal **MR Arthrogram:** Most sensitive for labral tears	• Rest, activity modification, physical therapy • Superior labral debridement, repair, or biceps tenodesis based on type of lesion (I-VII)
THORACIC OUTLET SYNDROME			
• Compression of neurovascular structure (artery, vein, brachial plexus) in the neck by 1st rib & scalene muscles • Also assoc. w/cervical ribs	**Hx:** Vague sx: pain & numbness/coolness **PE:** + Adson's test, + Wright test, decr. pulses	**XR:** Shoulder: normal C-spine: look for cervical rib **CXR:** r/o lung mass **EMG:** Brachial plexus	• Activity modification • PT & posture training • Rib (esp. cervical rib) or transverse process resection rarely indicated

Sprengel's Deformity



Radiograph shows omovertebral bone (arrows) connecting scapula to spinous processes of cervical vertebrae via osteochondral joint (J)

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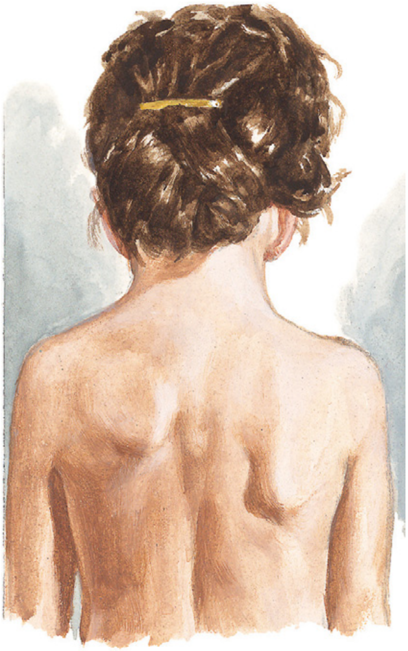
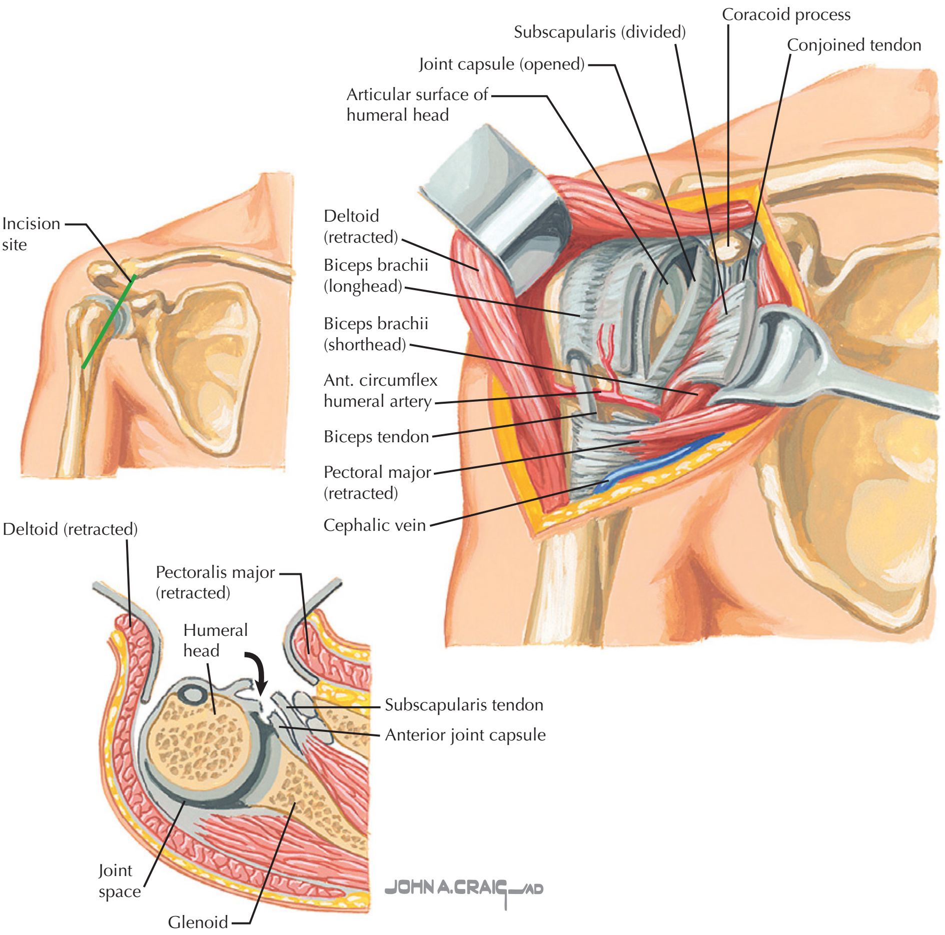


Child with congenital elevation of left scapula. Note shortness of neck on that side and tendency to torticollis

DESCRIPTION	EVALUATION	TREATMENT
SPRENGEL'S DEFORMITY		
• Small (hypoplastic), undescended scapula. Omovertebral bone connects C-spine (spinous process) to scapula • Associated with Klippel-Feil syndrome, scoliosis, kidney disease	**Hx:** Parents notice abnormal neck/scapula **PE:** Neck appears short/full; often decreased ROM (esp. abduction) **XR:** Look for omovertebral bone	• Mild: observation • Symptomatic: omovertebral bone resection, scapula distalization with muscle transfer, +/− clavicle osteotomy to protect brachial plexus

Deltopectoral Approach to Shoulder Joint


Subscapularis (divided)
Coracoid process
Conjoined tendon
Joint capsule (opened)
Articular surface of humeral head
Incision site
Deltoid (retracted)
Biceps brachii (longhead)
Biceps brachii (shorthead)
Ant. circumflex humeral artery
Biceps tendon
Pectoral major (retracted)
Cephalic vein
Deltoid (retracted)
Pectoralis major (retracted)
Humeral head
Subscapularis tendon
Anterior joint capsule
Joint space
Glenoid
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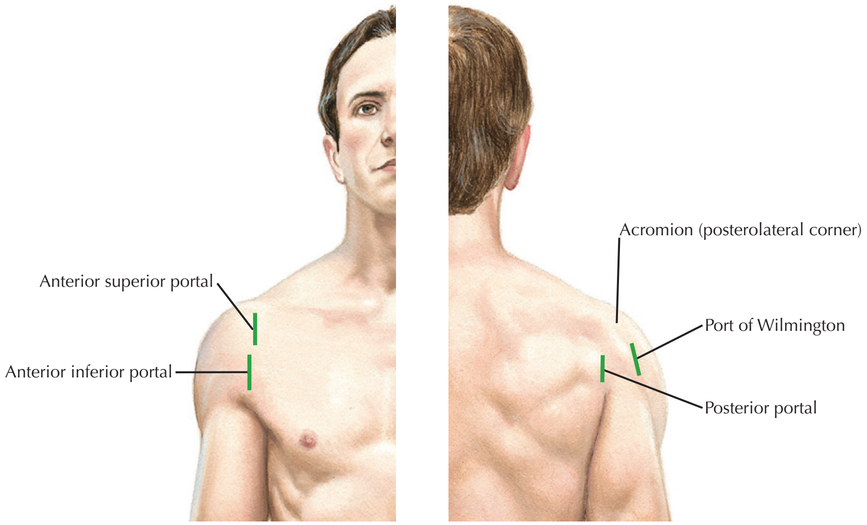
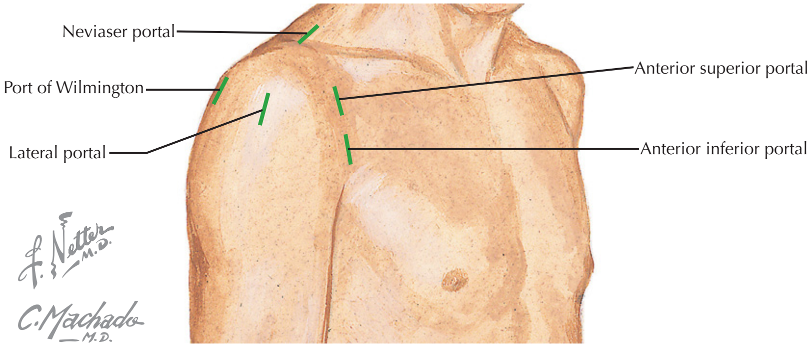
USES	INTERNERVOUS PLANE	DANGERS	COMMENT
ANTERIOR (DELTOPECTORAL) APPROACH			
• Open rotator cuff (esp. subscapularis) or labral repairs • Arthroplasty (hemi vs total) • Proximal humerus fxs	• Deltoid [axillary] • Pectoralis major [lateral & medial pectoral nerves]	• Musculocutaneous n. (with vigorous retraction of conjoined tendon) • Cephalic vein • Axillary nerve	• Subscapularis must be opened and repaired in approach • 3 vessels run along inf. border of subscap.; may need ligation • Adduct/ER protects axillary n.
COMPLICATIONS: Subscapularis rupture; neurapraxia (musculocutaneous or axillary nerve)			


Anterior superior portal
Anterior inferior portal
Acromion (posterolateral corner)
Port of Wilmington
Posterior portal


Neviaser portal
Port of Wilmington
Lateral portal
Anterior superior portal
Anterior inferior portal
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C. Machado M.D.

PORTAL	**PLACEMENT**	**DANGERS**	**COMMENT**
ARTHROSCOPY PORTALS			
Posterior	2cm down, 1cm medial to posterolateral corner of acromion (in "soft spot")	Posterior capsule/labrum	Primary viewing portal
Anterior superior	Both anterior portals are b/w the AC joint & lateral coracoid	Coracoacromial ligament and/or artery	Often used for instruments
Anterior inferior	In the rotator interval	Musculocutaneous nerve	Enters just above subscapularis tendon
Lateral	2cm distal to acromial edge	Axillary nerve (5cm distal)	Visualize RC and acromion
Wilmington	1cm ant, 1cm distal to posterolateral acromion corner	Safe portal	Useful in repairs of RC and labrum
Neviaser (supraspinatus)	Posterior to AC joint in sulcus	Rotator cuff	Anterior glenoid view

CHAPTER 4
Arm

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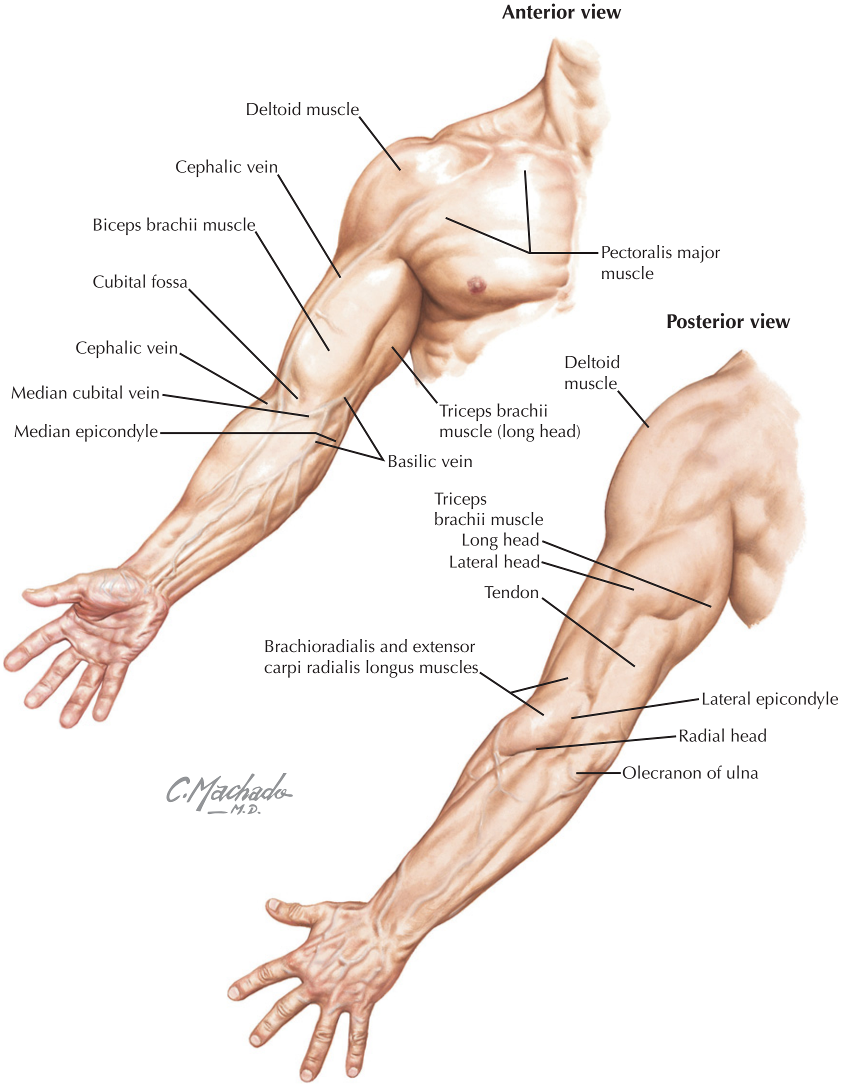
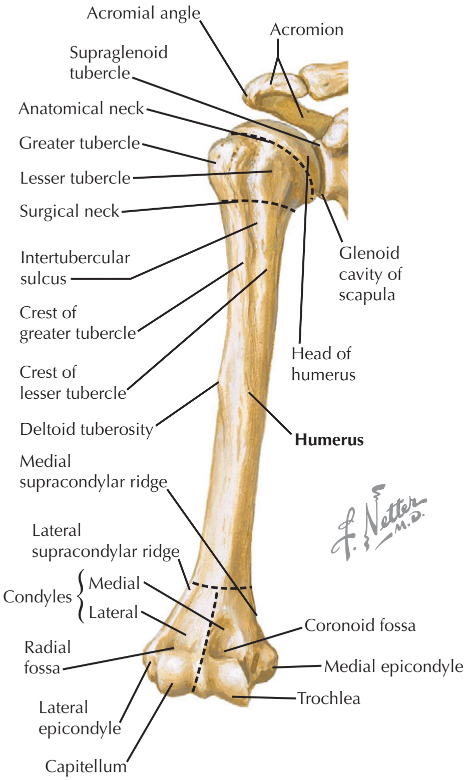
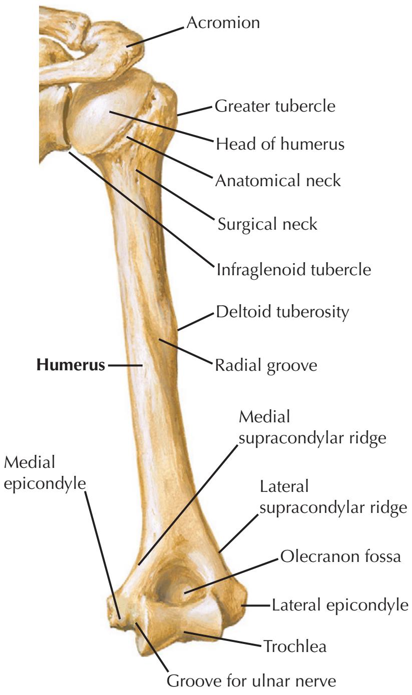

Anterior view
Deltoid muscle
Cephalic vein
Biceps brachii muscle
Cubital fossa
Cephalic vein
Median cubital vein
Median epicondyle
Pectoralis major muscle
Triceps brachii muscle (long head)
Basilic vein
Posterior view
Deltoid muscle
Triceps brachii muscle
Long head
Lateral head
Tendon
Brachioradialis and extensor carpi radialis longus muscles
Lateral epicondyle
Radial head
Olecranon of ulna
C. Machado M.D.

STRUCTURE	CLINICAL APPLICATION
Triceps	Can be palpated on the posterior aspect of the arm. A tendon avulsion/rupture can be palpated immediately proximal to the olecranon.
Biceps	Can be palpated on the anterior aspect of the arm.
Cubital fossa	Biceps tendon can be palpated here. If ruptured, the tendon cannot be palpated.
Lateral epicondyle	Site of common extensor origin. Tender in lateral epicondylitis ("tennis elbow")
Medial epicondyle	Site of common flexor origin. Tender in medial epicondylitis ("golfer's elbow")
Olecranon	Proximal tip of ulna. Tenderness can indicate fracture.
Radial head	Proximal end of radius. Tenderness can indicate fracture.


Acromial angle
Acromion
Supraglenoid tubercle
Anatomical neck
Greater tubercle
Lesser tubercle
Surgical neck
Intertubercular sulcus
Crest of greater tubercle
Crest of lesser tubercle
Deltoid tuberosity
Medial supracondylar ridge
Lateral supracondylar ridge
Condyles
Medial
Lateral
Radial fossa
Lateral epicondyle
Capitellum
Glenoid cavity of scapula
Head of humerus
Humerus
Coronoid fossa
Medial epicondyle
Trochlea

Anterior view

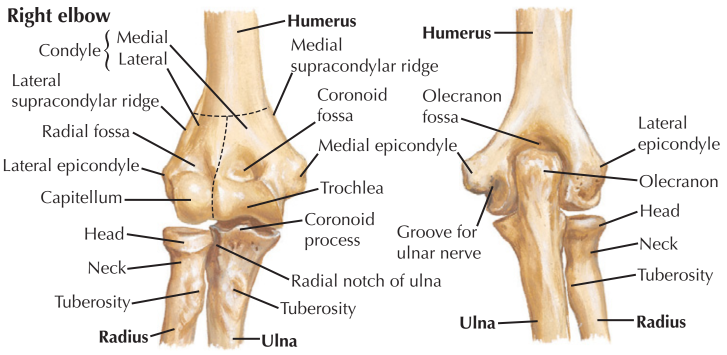

Acromion
Greater tubercle
Head of humerus
Anatomical neck
Surgical neck
Infraglenoid tubercle
Deltoid tuberosity
Radial groove
Humerus
Medial supracondylar ridge
Medial epicondyle
Lateral supracondylar ridge
Olecranon fossa
Lateral epicondyle
Trochlea
Groove for ulnar nerve

Posterior view

CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
	HUMERUS			
• Cylindrical long bone	**Primary**			• Limited remodeling potential in distal fxs
• Deltoid tuberosity	Shaft	6-7wk (fetal)	Birth	• Deltoid is a deforming force in shaft fractures
• Spiral groove: radial nerve runs in groove	**Secondary**			• Radial nerve can be entrapped in distal ⅓ humeral shaft fractures (Holstein-Lewis fx)
	Proximal (3):		14-18yr	
• Lateral condyle	Head	Birth		• Fx of lateral condyle common in pediatrics
◦ Capitellum (articular)	Tuberosities	1-4yr		• Capitellum aligns with radial head on x-ray
◦ Lateral epicondyle	**Distal (4):**		12-17yr	• Lat. epicondyle: origin of extensor mass & LCL
• Medial condyle	Capitellum	1yr		• Supracondylar process present 5%: ligament of Struthers may entrap median nerve
◦ Trochlea (articular)	Medial epicondyle	5yr		
◦ Medial epicondyle				• Med. epicondyle: origin of flexor mass & MCL
◦ Cubital tunnel	Trochlea	7yr		• Ulnar nerve runs post. to medial epicondyle
• Olecranon and coronoid fossae	Lateral epicondyle	11yr		• Fossae filled with fat; can be displaced in fx, resulting in “fat pad” on x-ray

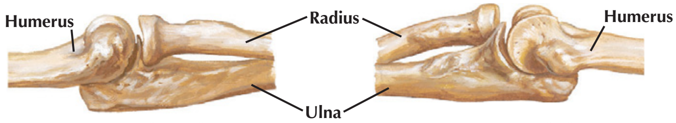
Elbow ossification order mnemonic: **C**aptain [capitellum] **R**oy [radial head] **M**akes [medial epicondyle] **T**rouble [trochlea] **O**n [olecranon] **L**eave [lateral epicondyle]; can be used to determine approximate age of patient.

Right elbow


Humerus
Condyle
Medial
Lateral
Medial supracondylar ridge
Lateral supracondylar ridge
Coronoid fossa
Radial fossa
Medial epicondyle
Lateral epicondyle
Trochlea
Capitellum
Coronoid process
Head
Neck
Radial notch of ulna
Tuberosity
Tuberosity
Radius
Ulna
Humerus
Olecranon fossa
Lateral epicondyle
Medial epicondyle
Olecranon
Head
Groove for ulnar nerve
Neck
Tuberosity
Ulna
Radius

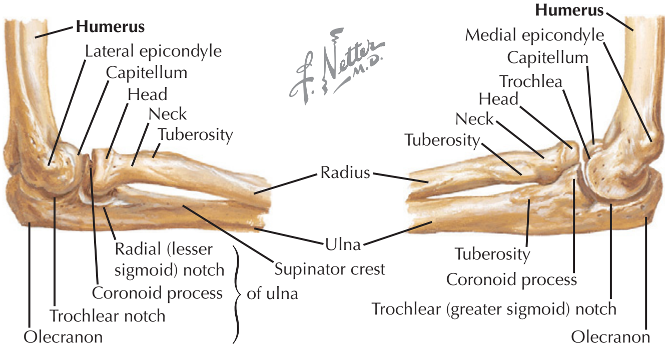
In extension: anterior view

In extension: posterior view


Humerus
Radius
Humerus
Ulna

In extension: lateral view

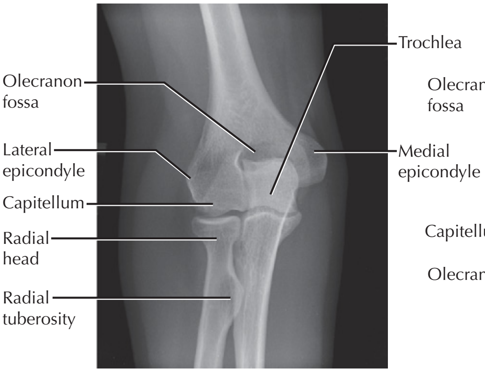
In extension: medial view


Humerus
Lateral epicondyle
Capitellum
Head
Neck
Tuberosity
Radius
Ulna
Radial (lesser sigmoid) notch
Coronoid process
Trochlear notch
Olecranon
Supinator crest of ulna
Humerus
Medial epicondyle
Capitellum
Trochlea
Head
Neck
Tuberosity
Tuberosity
Coronoid process
Trochlear (greater sigmoid) notch
Olecranon

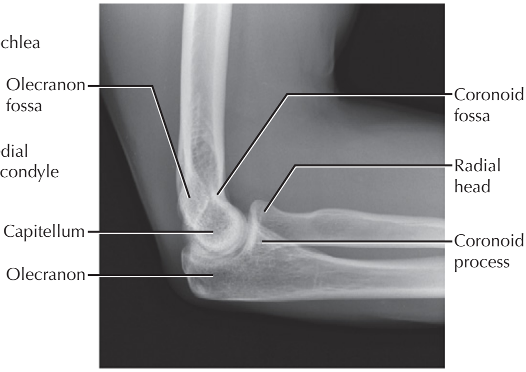
In 90° flexion: lateral view

In 90° flexion: medial view

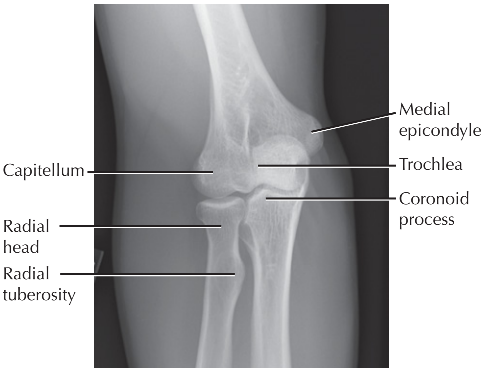
CHARACTERISTICS	OSSIFY	FUSE	COMMENTS
PROXIMAL RADIUS			
• Radial head & physis are intraarticular • Radial neck: 10-15° angulated	**Secondary** Head 2-3yr	16-18yr	• Anterolateral portion of radial head has less subchondral bone & is most susceptible to fracture • Radial head should always align with the capitellum
• Tuberosity: biceps insertion			• Tuberosity points ulnarly in supination
PROXIMAL ULNA			
• Olecranon • Coronoid process • Supinator crest	**Secondary** Olecranon 9yr	16-20yr	• Articulates with trochlea, part of greater notch • Coronoid provides anterior stability & MCL insertion • Lateral ulnar collateral ligament (LUCL) inserts on supinator crest
• Ulnar tuberosity • Greater sigmoid notch • Lesser sigmoid notch			• Brachialis inserts on ulnar tuberosity • Greater sigmoid notch: olecranon & coronoid • Lesser sigmoid (radial) notch: articulates with RH


Olecranon fossa
Lateral epicondyle
Capitellum
Radial head
Radial tuberosity
Trochlea
Medial epicondyle

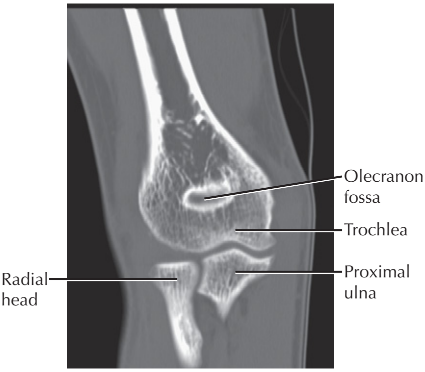
Elbow x-ray, AP


Olecranon fossa
Capitellum
Olecranon
Coronoid fossa
Radial head
Coronoid process

Elbow x-ray, lateral


Capitellum
Radial head
Radial tuberosity
Medial epicondyle
Trochlea
Coronoid process

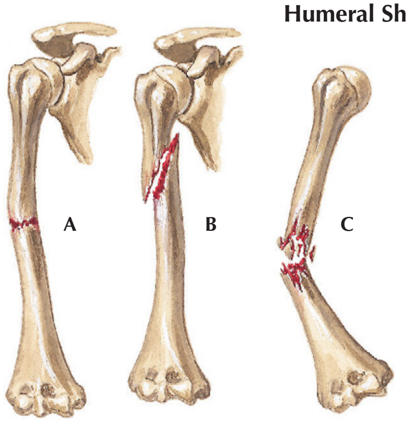
Elbow x-ray, oblique


Radial head
Olecranon fossa
Trochlea
Proximal ulna

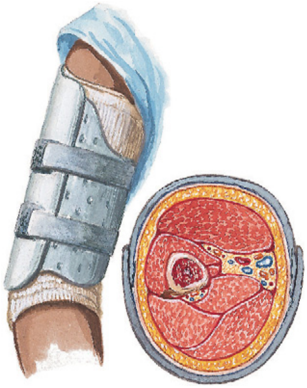
Elbow CT, coronal

RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
Anteroposterior	Elbow extended, beam perpendicular to plate	Elbow joint, distal humerus, proximal radius and ulna	Fractures, dislocations, arthritis/DJD, supracondylar process
Lateral	Elbow flexed 90°, beam from lateral to radial head	Elbow joint, fat pads (fat is displaced by fracture hematoma)	Fractures (esp. peds: fat pads, anterior humeral line), DJD (osteophytes)
Oblique	Elbow extended, rotated 30°	Alignment & position of bones	Subtle fx (radial head, occult fx)
Radiocapitellar	Lateral, beam 45° to elbow	Isolates capitellum/radial head	Fx: radial head, capitellum, coronoid
		OTHER STUDIES	
CT	Axial, coronal, and sagittal	Articular congruity, bone healing, bone alignment	Fractures (esp. coronoid, comminuted intraarticular fx)
MR	Sequence protocols vary	Soft tissues (ligaments, tendons, cartilage), bones	Ligament (e.g., MCL) & tendon (e.g., biceps) rupture, OCD
Bone scan		All bones evaluated	Infection, stress fractures, tumors

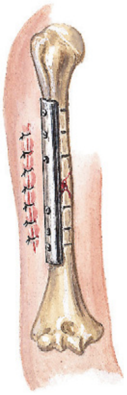
Humeral Shaft Fracture



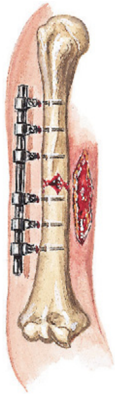
A. Transverse fracture of midshaft
B. Oblique (spiral) fracture
C. Comminuted fracture with marked angulation



After initial swelling subsides, most fractures of shaft of humerus can be treated with functional brace of interlocking anterior and posterior components held together with Velcro straps.

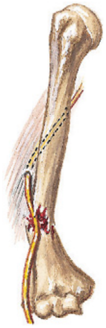


Open reduction and fixation with compression plate indicated under special conditions.



Fracture aligned and held with external fixator. Most useful for wounds requiring frequent changes of dressing.

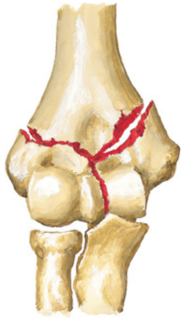
F. Netter M.D.
D. Mascaro



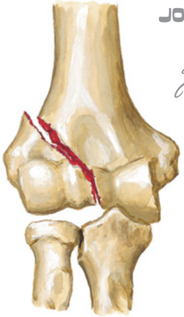
Entrapment of radial nerve in fracture of shaft of distal humerus may occur at time of fracture; must also be avoided during reduction.

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
HUMERUS SHAFT FRACTURE			
• Common long bone fracture • Mechanism: fall or direct blow • Displacement based on fracture location and muscle insertion sites. Pectoralis and deltoid are primary deforming forces. • High union rates • Site of pathologic fractures	**Hx:** Trauma/fall, pain and swelling **PE:** Swelling +/− deformity, humerus is TTP Good neuro. exam (esp. radial n.) **XR:** AP & lateral of arm (also shoulder & elbow series) **CT:** Not usually needed	Descriptive: • Location: site of fracture • Displaced, angulated, or comminuted • Pattern: transverse, spiral, oblique	• Cast/brace: minimally displaced/acceptable alignment • Acceptable: <3cm shortening <20° A/P angulation <30° varus/valgus angulation • Surgical treatment: open fx, floating elbow, segmental fx, polytrauma, vascular injury • Options: ORIF, external fixation, IM nail
COMPLICATIONS: Radial nerve palsy (esp. distal ⅓ fractures [Holstein-Lewis]): most are neurapraxia and resolve spontaneously; nerve exploration is controversial; nonunion/malunion are uncommon.			

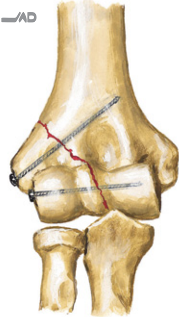
Distal Humerus Fracture



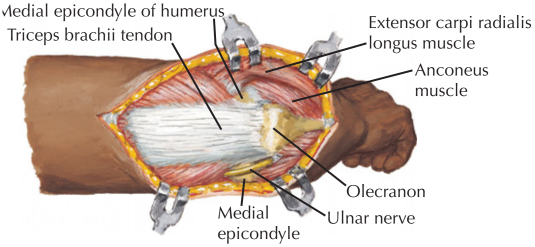
Intercondylar (T or Y) fracture of distal humerus



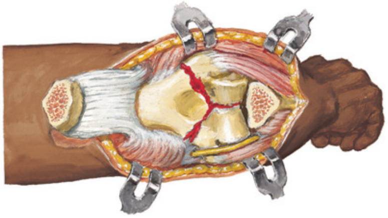
Fracture of lateral condyle of humerus. Fracture of medial condyle less common



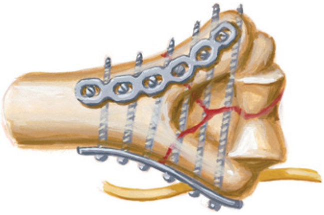
Fractured condyle fixed with one or two compression screws



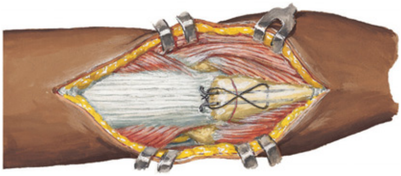
Open (transolecranon) repair. Posterior incision skirts medial margin of olecranon, exposing triceps brachii tendon and olecranon. Ulnar nerve identified on posterior surface of medial epicondyle. Incisions made along each side of olecranon and triceps brachii tendon



Olecranon osteotomized and reflected proximally with triceps brachii tendon



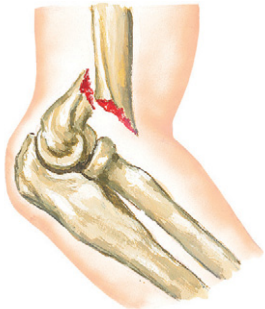
Articular surface of distal humerus reconstructed and fixed with transverse screw and buttress plates with screws. Ulnar nerve may be transposed anteriorly to prevent injury. Lateral column fixed with posterior plate and medial column fixed with plate on the medial ridge.



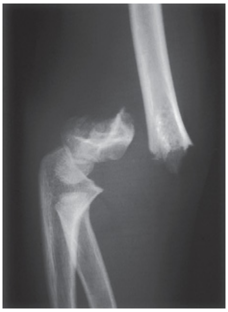
Olecranon reattached with longitudinal Kirschner wires and tension band wire wrapped around them and through hole drilled in ulna

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
DISTAL HUMERUS FRACTURE			
• Most often intraarticular (adults); extraarticular (supracondylar) fx uncommon in adults • Mechanism: fall • Unicondylar or bicondylar • Other: epicondyle, capitellum, trochlea fxs all less common	**Hx:** Trauma/fall, pain, esp. w/ elbow ROM (decreased) **PE:** Swelling & tenderness Good neurovascular exam **XR:** Elbow series **CT:** Essential for complete evaluation of fracture/joint	Descriptive: • Uni or bicondylar • T, Y, λ type • Displaced, angulated comminuted (esp. coronal split)	• Nonoperative: rarely indicated • Surgical: ORIF (plates & screws) • Ulnar nerve often needs to be transposed anteriorly • Early ROM is important • Total elbow arthroplasty: if fx is too comminuted for ORIF
COMPLICATIONS: Elbow stiffness, heterotopic ossification (prophylaxis is indicated), ulnar nerve palsy, nonunion			

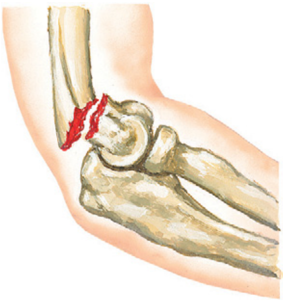
Supracondylar Fractures



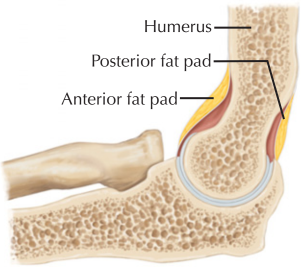
Extension type
Posterior displacement of distal fragment (most common)



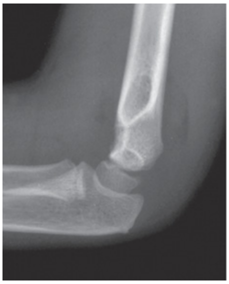
Lateral radiograph



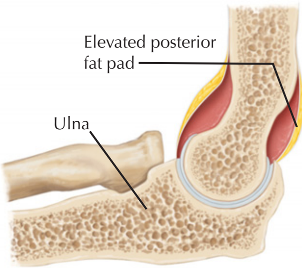
Flexion type
Anterior displacement of distal fragment (uncommon)



Normal



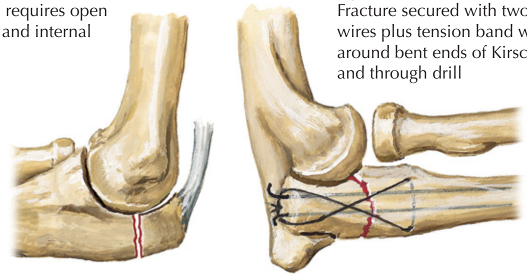
Lateral radiograph of elbow in a 5-year-old sustaining injury to left elbow. Radiograph shows elevation of anterior and posterior fat pads. No apparent fracture on this view, but subsequent radiographs confirmed presence of a nondisplaced supracondylar humerus fracture.



Fracture

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
SUPRACONDYLAR HUMERUS FRACTURE			
• Common pediatric fracture • Extraphyseal fx at thin portion of bone (1mm) between distal humeral fossae • Extension type most common • Malreduction leads to deformity: cubitus varus is most common • Relatively high incidence of neurovascular injury	**Hx:** Fall, pain, will not move arm, +/– deformity **PE:** Swelling +/– deformity. Good neurovascular exam (esp. AIN, radial n., pulses) **XR:** Elbow series. Lateral view: anterior humeral line is anterior to capitellum center in displaced fxs. Posterior fat pad indicates fx.	• Extension type (Gartland) ∘ I: Nondisplaced ∘ II: Partially displaced (post. cortex intact) ∘ III: Displaced (no cortical continuity) • Flexion type (uncommon)	• Type I: Long arm cast • Types II & III: Closed reduction & percutaneous pinning, 2 or 3 pins (crossed or divergent) Medial pins can injure ulnar nerve • Open reduction for irreducible fractures (uncommon) • Explore pulseless/unperfused extremity for artery entrapment
COMPLICATIONS: Malunion (cubitus varus #1); neurovascular (median nerve/AIN #1, radial nerve, brachial artery)			

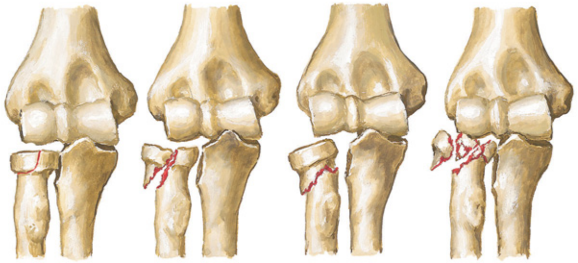
Olecranon fracture



Displaced fracture of olecranon requires open reduction and internal fixation

Open reduction of olecranon fracture. Fracture secured with two Kirschner wires plus tension band wire passed around bent ends of Kirschner wires and through drill

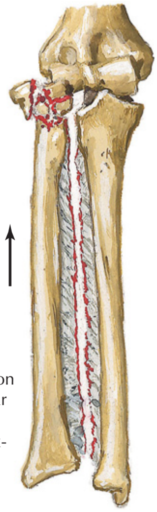
Fracture of head and neck of radius



Type I: nondisplaced or minimally displaced.

Type II: displaced single fragment (usually >2 mm) of the head or angulated (usually >30°) of the neck.

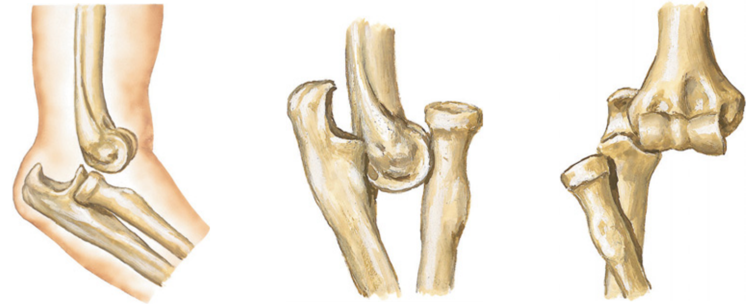
Type III: severely comminuted fractures of the radial head and neck.



Comminuted fracture of radial head with dislocation of distal radioulnar joint, proximal migration of radius, and tear of interosseous membrane (Essex-Lopresti fracture)

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
OLECRANON FRACTURE			
• Mechanism: fall directly onto elbow or onto hand • Intraarticular fracture: congruity important for good results • Triceps tendon is a deforming force on proximal fragment	**Hx:** Trauma (usually fall), pain and swelling **PE:** Tenderness, limited elbow extension. Neuro exam, esp. ulnar nerve **XR:** Elbow series **CT:** Better defines fracture	Colton: • I. Nondisplaced: <2mm • II. Displaced ◦ Avulsion ◦ Transverse/oblique ◦ Comminuted ◦ Displaced fx-dx	• Nondisplaced: Long arm cast 3 weeks, then gentle ROM • Displaced: ◦ Transverse: ORIF tension band or IM screw. ◦ Oblique/comminuted: ORIF with contoured plate • Excise & reattach tendon
COMPLICATIONS: Painful hardware, elbow stiffness, nonunion, arthritis (posttraumatic), ulnar nerve injury			
RADIAL HEAD FRACTURE			
• Mechanism: fall onto hand • Intraarticular fracture: anterolateral portion is weaker and is most common fracture site • Essex-Lopresti: RH fx w/ disruption of IM membrane & DRUJ • Associated w/ elbow dislocation	**Hx:** Trauma/fall, pain **PE:** Decreased motion (esp. pronosupination) Check DRUJ stability **XR:** Elbow series; radiocapitellar view is helpful, +/− fat pad sign **CT:** Useful in types II-IV	Mason: 4 types • I: Nondisplaced (<2mm) • II: Single displaced fragment • III: Comminuted • IV: Fracture with elbow dislocation	• Type I: Elbow aspiration, sling for 3 days, early ROM • Type II: ORIF (esp. for mechanical block to motion) • Type III: Radial head excision and/or RH arthroplasty • Essex-Lopresti: radial head arthroplasty is required
COMPLICATIONS: Elbow stiffness or instability; Wrist instability (Essex-Lopresti)			

Elbow dislocation

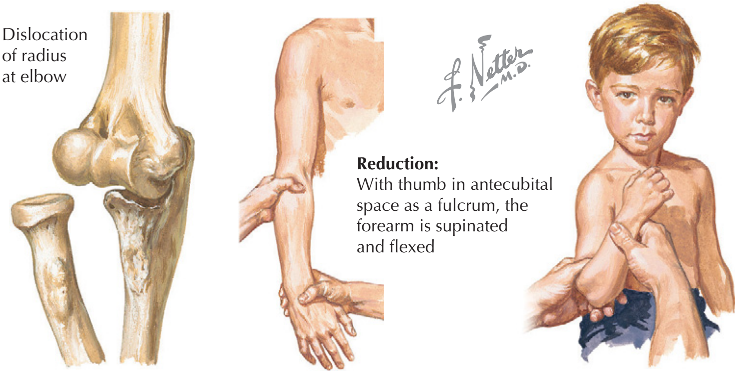


Posterior dislocation. Note prominence of olecranon posteriorly and distal humerus anteriorly.

Divergent dislocation, anterior-posterior type (rare). Medial-lateral type may also occur (extremely rare).

Lateral dislocation (uncommon)

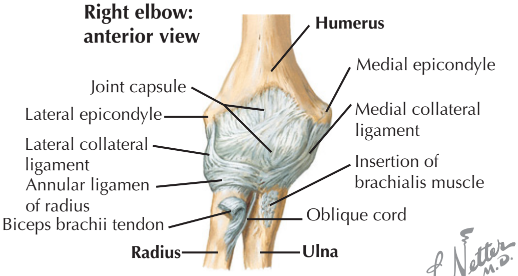
Radial head subluxation



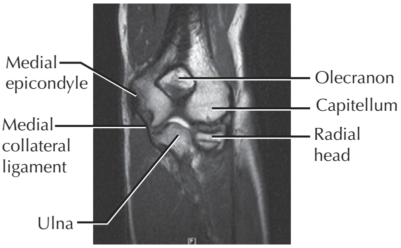
Reduction:
With thumb in antecubital space as a fulcrum, the forearm is supinated and flexed

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
ELBOW DISLOCATION			
• Mechanism: usually a fall in young patient • #3 most common dislocation • Associated with fractures: "Terrible triad" = elbow dx with radial head & coronoid fractures • Collateral ligaments & anterior capsule are typically all torn	**Hx:** Trauma/fall, inability to move elbow **PE:** Swelling, deformity, limited/no elbow ROM Good neurovasc. exam **XR:** Elbow series **CT:** To define associated fractures	By direction of forearm bones: • Posterior ◦ Posterolateral (>80%) • Medial • Lateral (rare) • Anterior (rare) • Divergent (rare)	• Acute: closed reduction ◦ Stable: splint for 7-10d ◦ Unstable: splint for 2-3wk • Open reduction for irreducible dxs and/or ORIF fxs • Hinged external fixation for grossly unstable elbows
COMPLICATIONS: Elbow stiffness and instability, neurovascular injury (median and ulnar nerves, brachial artery)			
RADIAL HEAD SUBLUXATION (NURSEMAID'S ELBOW)			
• Mechanism: usually a pull on the hand by an adult • Very common in toddlers • Decreased with increasing age • Annular ligament stretches & radial head subluxates	**Hx:** Child pulled by hand, child will not use arm **PE:** Elbow flexed, pronated. RH tender **XR:** Elbow series; normal, often not needed	None	• Closed reduction: fully extend elbow, fully supinate, then flex with gentle pressure on radial head. Usually a click or pop is felt as it reduces. • Immobilization rarely indicated
COMPLICATIONS: Recurrence			

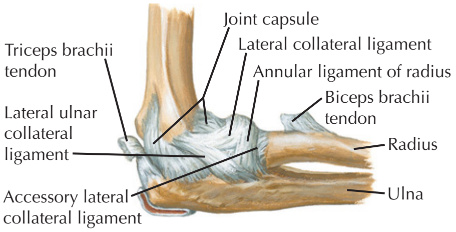
Right elbow: anterior view


Humerus
Medial epicondyle
Joint capsule
Lateral epicondyle
Medial collateral ligament
Lateral collateral ligament
Insertion of brachialis muscle
Annular ligamen of radius
Oblique cord
Biceps brachii tendon
Radius
Ulna

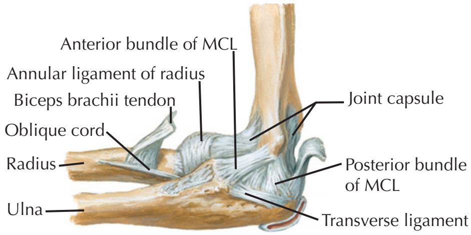
MRI coronal, elbow


Medial epicondyle
Olecranon
Capitellum
Medial collateral ligament
Radial head
Ulna

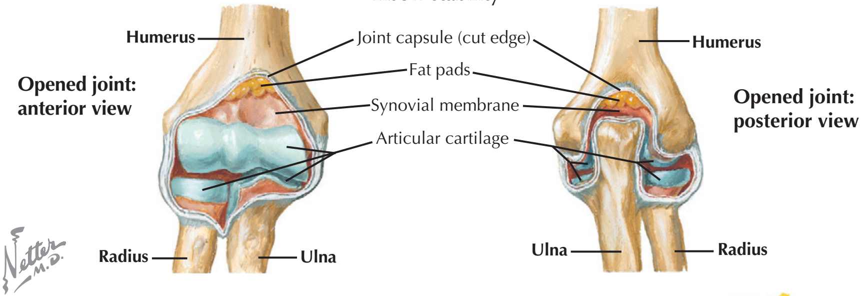
In 90° flexion: lateral view


Joint capsule
Lateral collateral ligament
Triceps brachii tendon
Annular ligament of radius
Biceps brachii tendon
Lateral ulnar collateral ligament
Radius
Accessory lateral collateral ligament
Ulna

In 90° flexion: medial view


Anterior bundle of MCL
Annular ligament of radius
Biceps brachii tendon
Joint capsule
Oblique cord
Radius
Posterior bundle of MCL
Ulna
Transverse ligament

LIGAMENTS	ATTACHMENTS	COMMENTS
ELBOW		
• The elbow comprises three articulations: 1. Ulnohumeral (trochlea and greater sigmoid notch): Ginglymus (hinge) joint 2. Radiocapitellar (radial head and capitellum): Trochoid (pivot) joint 3. Proximal radioulnar (radial head and lesser sigmoid notch) • Primary function is as a lever for lifting and placing the hand appropriately in space • Two primary motions: 1. Flexion and extension: 0-150° (functional ROM: 100° [30-130°]); axis is the trochlea 2. Pronosupination: 70° pro. – 80° sup. (functional ROM: 100° [50° pro. – 50° sup.]); axis is RC joint • Stability provided by combination of osseous (articulations) and ligamentous restraints; carrying angle 11-16° valgus		
Medial (Ulnar) Collateral (MCL)		
Anterior bundle	Inf. medial epicondyle to medial coronoid process ("sublime tubercle")	Most important restraint to valgus stress, always taut; usually ruptures off coronoid
Posterior bundle	Medial epicondyle to sigmoid notch	Taut in/resists valgus in flexion (>90º)
Transverse bundle	Med. olecranon to inf. medial coronoid	Stabilizes the greater sigmoid notch
Lateral (Radial) Collateral (LCL)		
Lateral collateral (LCL)	Lat. epicondyle to ant. annular lig.	Varus restraint; stabilizes annular ligament
Lateral ulnar collateral (LUCL)	Lateral epicondyle to supinator crest of the ulna	Buttress to radial head subluxation; injury results in posterolateral rotatory instability
Accessory lateral collateral	Annular ligament to supinator crest	Stabilizes annular ligament during varus stress
Annular ligament	Anterior and posterior portions of sigmoid notch	Allows radial head rotation; stretched or torn in radial head subluxation or dislocation
Other		
Capsule	Surrounds joint	Secondary stabilizer, prone to contracture
Quadrate ligament	Anterolateral ulna to anterior radial neck (under the annular ligament)	Tight in supination, stabilizes the proximal radioulnar joint (PRUJ)
Oblique cord	Proximal lateral ulna to radial neck	Stabilizes joint during pronosupination


Elbow stability
Opened joint: anterior view
Humerus
Joint capsule (cut edge)
Fat pads
Synovial membrane
Articular cartilage
Radius
Ulna
Opened joint: posterior view
Humerus
Ulna
Radius

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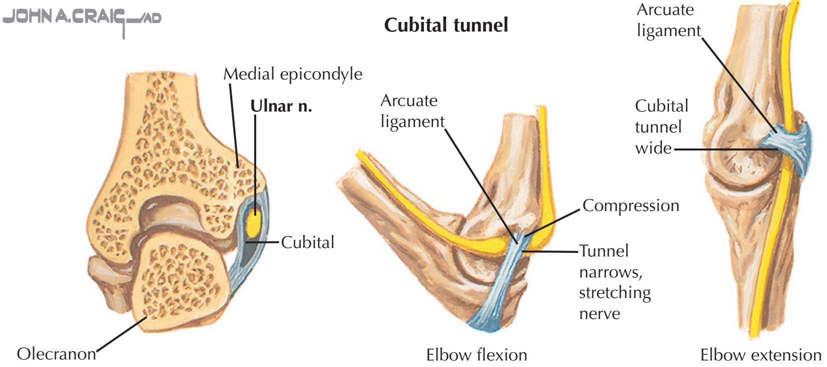
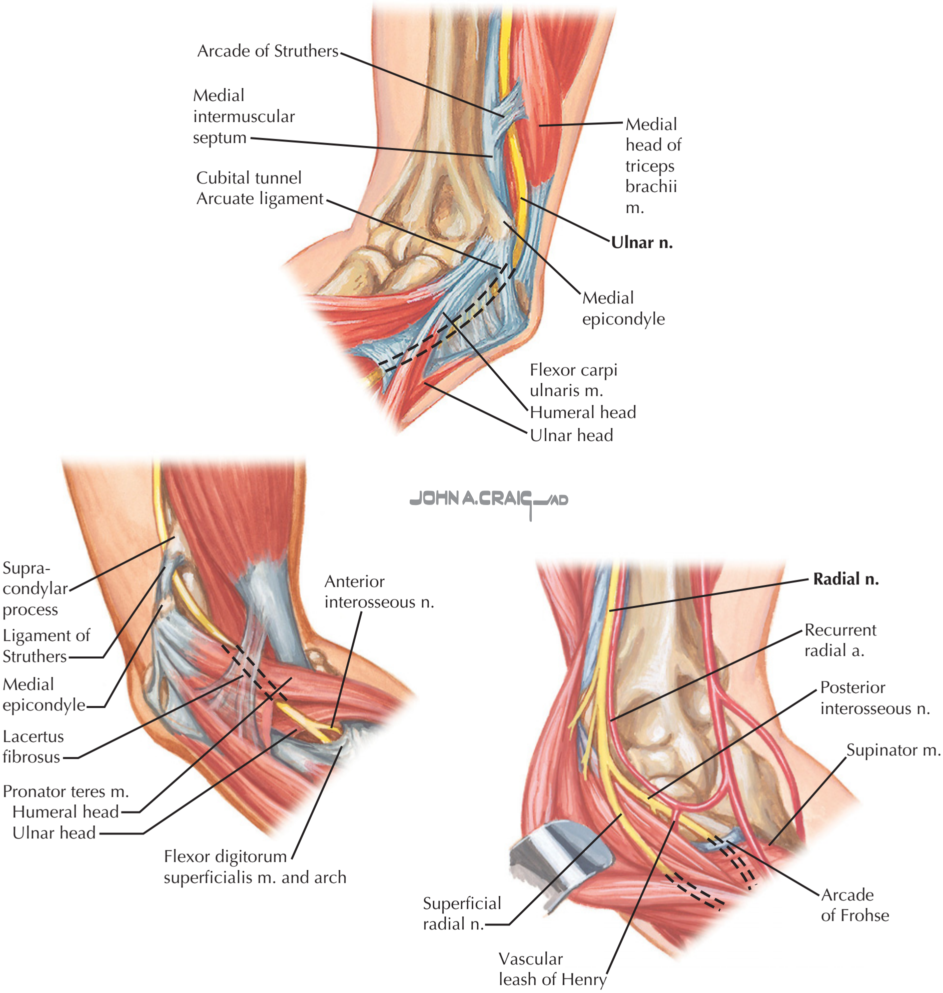

Cubital tunnel
Medial epicondyle
Ulnar n.
Cubital
Olecranon
Arcuate ligament
Compression
Tunnel narrows, stretching nerve
Elbow flexion
Arcuate ligament
Cubital tunnel wide
Elbow extension

ELBOW STABILITY	
Primary Stabilizers	
Ulnohumeral articulation	Primary restraint to valgus <20° or >120° of flexion Primary restraint to varus in extension (2° in flexion)
Medial collateral ligament (MCL) (esp. anterior bundle)	Primary restraint to valgus between 20-120° of flexion Anterior bundle is always taut, post. bundle taut >90°
Lateral collateral ligament (LCL) (esp. LUCL)	Primary restraint to varus in flexion (2° in extension) LUCL prevents subluxation of radial head (e.g., PLRI)
Secondary Stabilizers	
Radiocapitellar articulation (radial head)	Restraint to valgus from 0-30º of flexion
Anterior and posterior capsule	Restraint to both varus and valgus stress
Common flexor and extensor origins	Dynamic forces act to restrain both varus and valgus stress

STRUCTURE	COMPONENTS	COMMENTS
CUBITAL TUNNEL		
Borders	• Roof: Arcuate (Osborne's) ligament From med. epicondyle to olecranon	• Tightens in flexion, compresses ulnar nerve within cubital tunnel
	• Floor: Medial collateral ligament (MCL)	• Can be injured in decompression surgery
	• Posterior: Medial head of the triceps	• Does not typically compress the nerve
	• Anterior: Medial epicondyle	• Medial epicondylectomy occasionally indicated
	• Lateral: Olecranon	• Does not compress nerve
Contents	• Nerve: Ulnar nerve	• Compressed in cubital tunnel syndrome
• Fractures (malunion) of the medial condyle can cause ulnar nerve entrapment in the cubital tunnel. • Arcuate ligament is also known as Osborne's ligament/fascia and the cubital tunnel retinaculum. • See Forearm chapter for radial tunnel.		


Arcade of Struthers
Medial intermuscular septum
Cubital tunnel
Arcuate ligament
Medial head of triceps brachii m.
Ulnar n.
Medial epicondyle
Flexor carpi ulnaris m.
Humeral head
Ulnar head
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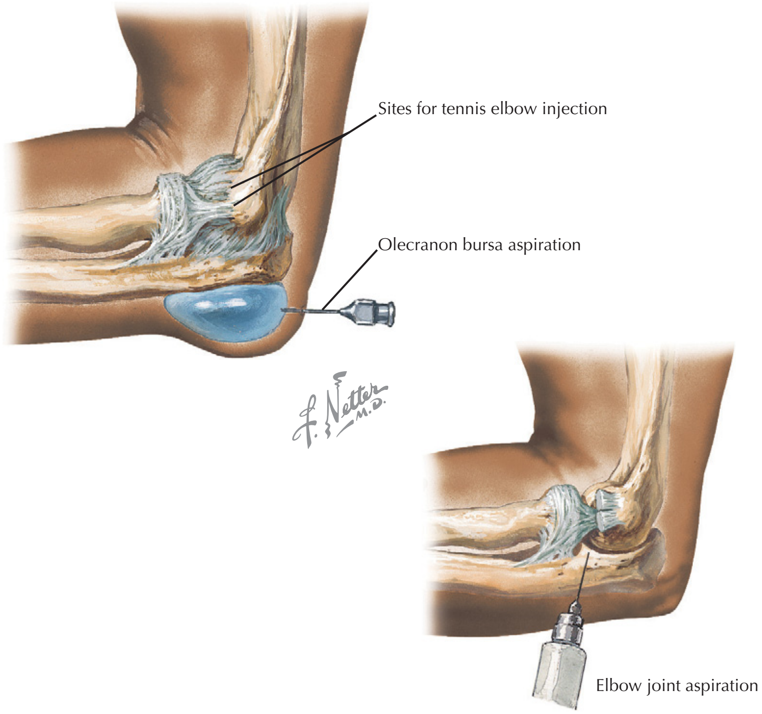
Supra-condylar process
Ligament of Struthers
Medial epicondyle
Lacertus fibrosus
Pronator teres m.
Humeral head
Ulnar head
Anterior interosseous n.
Flexor digitorum superficialis m. and arch
Radial n.
Recurrent radial a.
Posterior interosseous n.
Supinator m.
Arcade of Frohse
Superficial radial n.
Vascular leash of Henry

STRUCTURE	DESCRIPTION	COMMENTS
OTHER STRUCTURES		
Fat pads	Located in both the coronoid and olecranon fossae, engaged in full flexion or extension	Can be displaced by fracture hematoma and seen on x-ray as a lucency ("sail sign")
Olecranon bursa	At the tip of the olecranon process	Can become inflamed or infected
Ligament of Struthers	A fibrous band running from an anomalous supracondylar process to medial epicondyle	Can compress the median nerve proximally
Biceps aponeurosis (lacertus fibrosus)	Fascial band from distal biceps and tendon that runs to deep forearm fascia	Covers median nerve and brachial artery and can compress median nerve
Arcade of Struthers	Thickened fascia from IM septum to triceps (medial head), 8cm proximal to epicondyle	Occurs in 70% of population; can compress ulnar nerve proximal to cubital tunnel
Leash of Henry	Branches of recurrent radial artery	Can compress radial nerve/PIN



STEPS

ELBOW ARTHROCENTESIS

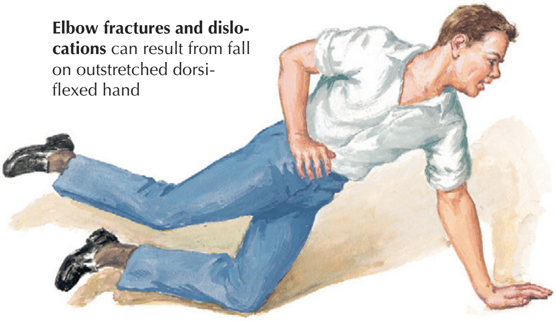
1. Flex and extend elbow, palpate lateral condyle, radial head, and olecranon laterally; feel triangular sulcus ("soft spot") between all three
2. Prep skin over sulcus (iodine/antiseptic soap)
3. Anesthetize skin locally (quarter size spot)
4. May keep arm in extension or flex it. Insert needle in "triangle" between bony landmarks (aim to medial epicondyle)
5. Fluid should aspirate easily
6. Dress injection site

OLECRANON BURSA ASPIRATION

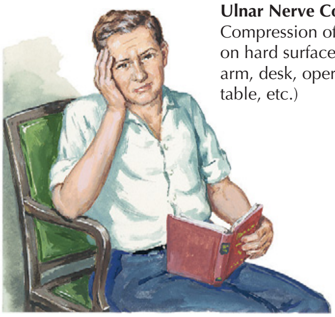
1. Prep skin over olecranon (iodine/antiseptic soap)
2. Anesthetize skin locally (quarter size spot)
3. Insert 18-gauge needle into fluctuant portion of the bursa and aspirate fluid
4. If suspicious of infection, send fluid for Gram stain and culture
5. Dress injection site

TENNIS ELBOW INJECTION

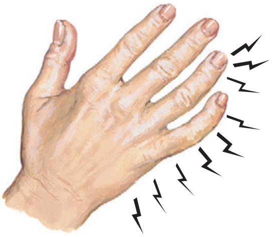
1. Ask patient about allergies
2. Flex elbow 90°, palpate ECRB insertion (point of maximal tenderness) on the lateral epicondyle
3. Prep skin over lateral elbow (iodine/antiseptic soap)
4. Anesthetize skin locally (quarter size spot)
5. Insert 22-gauge or smaller needle into ECRB tendon at its insertion on the lateral epicondyle. Aspirate to ensure needle is not in a vessel, then inject 2-3ml of 1:1 local/corticosteroid preparation (fan out injection in broad tendon).
6. Dress insertion site
7. Annotate improvement in symptoms



Elbow fractures and dislocations can result from fall on outstretched dorsiflexed hand

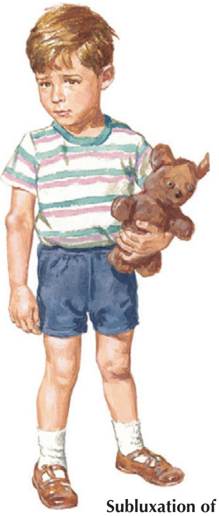


Ulnar Nerve Compression Compression of nerve on hard surface (chair arm, desk, operating table, etc.)

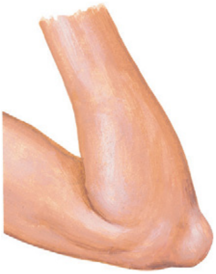


Numbness and tingling in ulnar nerve distribution in hand. Interosseous wasting between thumb and index finger

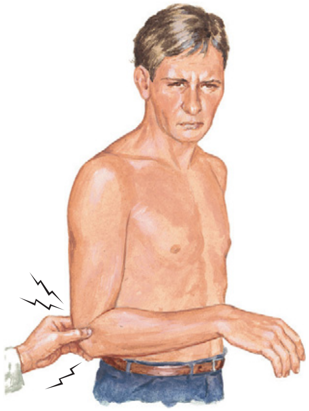
QUESTION	ANSWER	CLINICAL APPLICATION
1. Age	Young	Dislocation, fracture
	Middle aged, elderly	Tennis elbow (epicondylitis), nerve compression, arthritis
2. Pain		
a. Onset	Acute	Dislocation, fracture, tendon avulsion/rupture, ligament injury
	Chronic	Arthritis, cervical spine pathology
b. Location	Anterior	Biceps tendon rupture, arthritis, elbow contracture
	Posterior	Olecranon bursitis (inflammatory or septic)
	Lateral	Lateral epicondylitis, fracture (especially radial head)
	Medial	Medial epicondylitis, nerve entrapment, fracture, MCL strain
	Night pain/at rest	Infection, tumor
c. Occurrence	With activity	Ligamentous and/or tendinous etiology
3. Stiffness	Without locking	Arthritis, effusions (trauma), contracture
	With locking	Loose body, lateral collateral ligament injury
4. Swelling	Over olecranon	Olecranon bursitis. Other: dislocation, fracture, gout
5. Trauma	Fall on elbow, hand	Dislocation, fracture
6. Activity	Sports, repetitive motion	Epicondylitis, ulnar nerve palsy
	Throwing	MCL strain or rupture
7. Neurologic symptoms	Pain, numbness, tingling	Nerve entrapments (multiple possible sites), cervical spine pathology, thoracic outlet syndrome
8. History of arthritides	Multiple joints involved	Lupus, rheumatoid arthritis, psoriasis, gout



Subluxation of head of radius
("pulled elbow"/ "nursemaid's")



Olecranon bursitis
(student's elbow)



Epicondylitis (tennis elbow)
Exquisite tenderness over lateral or medial epicondyle of humerus

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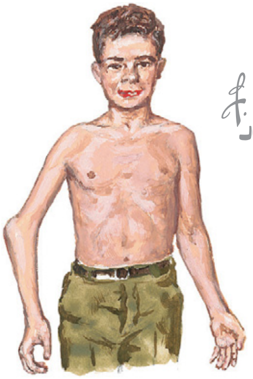
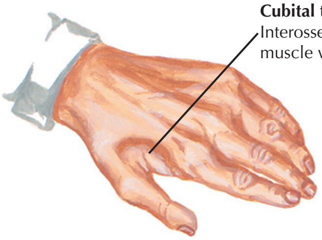
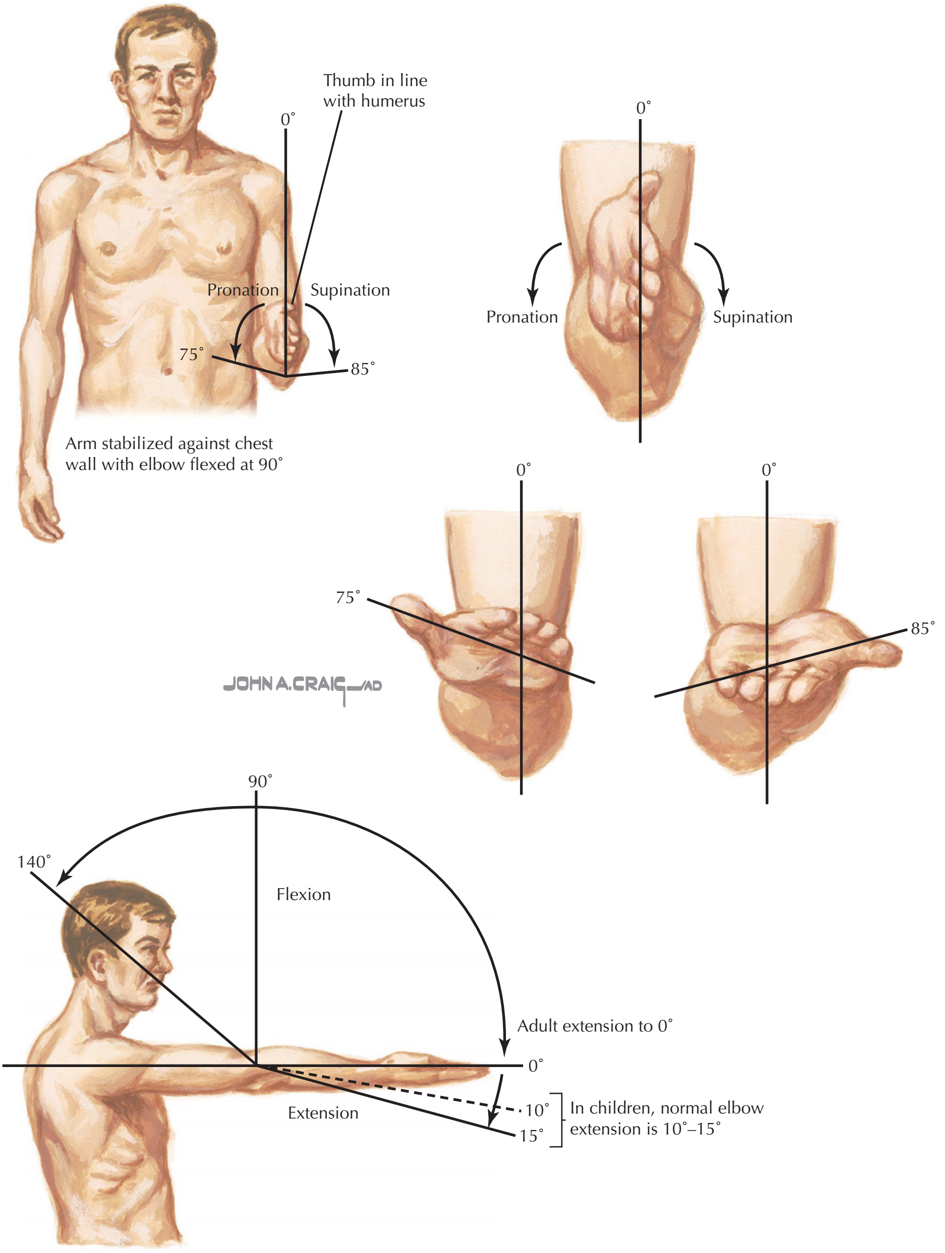


Cubitus varus deformity
Malunion of a supracondylar fracture can result in this deformity.

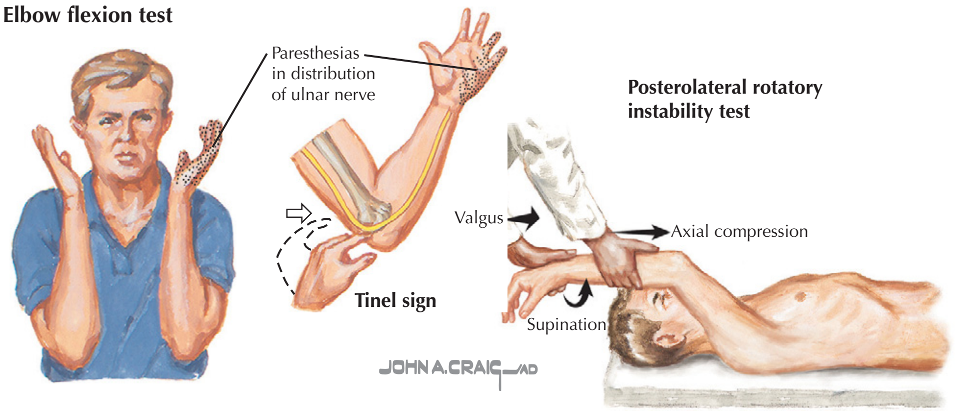


Cubital tunnel syndrome
Interosseous muscle wasting

EXAM/OBSERVATION	TECHNIQUE	CLINICAL APPLICATION
	INSPECTION	
Unwilling to use arm	Observe patient (child)	Fracture, dislocation, radial head subluxation (nursemaid's elbow)
Gross deformity, swelling	Compare both sides	Dislocation, fracture, bursitis
Carrying angle (normal 5-15°)	Negative (<5°) Positive (>15°)	Cubitus varus (e.g., supracondylar fracture) Cubitus valgus (e.g., lateral epicondyle fracture)
Muscle wasting	Inspect hand muscles	Nerve entrapment (e.g., cubital tunnel syndrome)
	PALPATION	
Medial	Epicondyle and supracondylar line Ulnar nerve in ulnar groove	Pain: medial epicondylitis (golfer's elbow), fracture, MCL rupture/strain Paresthesias indicate ulnar nerve entrapment
Lateral	Epicondyle and supracondylar line Radial head	Pain: lateral epicondylitis (tennis elbow), fracture Pain: arthritis, fracture, synovitis
Anterior	Biceps tendon in antecubital fossa	Pain: absence of tendon indicates biceps tendon rupture
Posterior	Flex elbow: olecranon, olecranon fossa, triceps tendon	Olecranon bursitis, triceps tendon rupture


Thumb in line with humerus
0°
Pronation
Supination
75°
85°
Arm stabilized against chest wall with elbow flexed at 90°
0°
Pronation
Supination
0°
0°
75°
85°
JOHN A.CRAIG MD
90°
140°
Flexion
Adult extension to 0°
0°
10°
15°
Extension
In children, normal elbow extension is 10°–15°

EXAM/OBSERVATION	TECHNIQUE	CLINICAL APPLICATION
RANGE OF MOTION		
Flex and extend	Elbow at side: flex and extend at elbow	Normal: 0° to 140-150°; note if PROM >AROM
Pronate and supinate	Tuck elbows, thumbs up, rotate forearm	Normal: supinate 80-85°, pronate 75-80°


Elbow flexion test
Paresthesias in distribution of ulnar nerve
Valgus
Tinel sign
Posterolateral rotatory instability test
Axial compression
Supination
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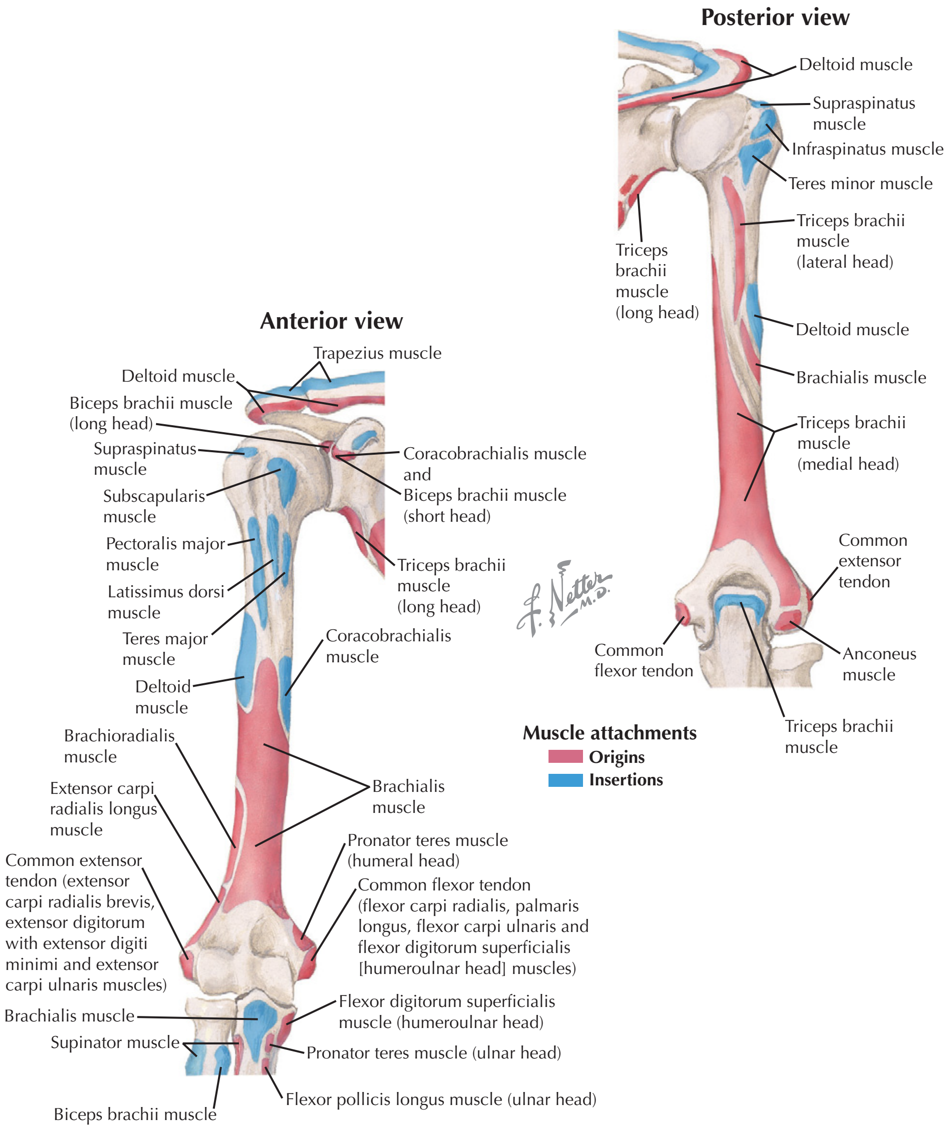
EXAM	TECHNIQUE	CLINICAL APPLICATION
NEUROVASCULAR		
Sensory		
Axillary n. (C5)	Proximal lateral arm	Deficit indicates corresponding nerve/root lesion
Radial n. (C5)	Inferolateral and posterior arm	Deficit indicates corresponding nerve/root lesion
Medial cutaneous n. of arm (T1)	Medial arm	Deficit indicates corresponding nerve/root lesion
Motor		
Musculocutaneous n. (C5-6)	Resisted elbow flexion	Weakness = Brachialis/biceps or nerve/root lesion
Musculocutaneous n. (C6)	Resisted supination	Weakness = Biceps or corresponding nerve/root lesion
Median n. (C6)	Resisted pronation	Weakness = Pronator teres or nerve/root lesion
Radial n. (C7)	Resisted elbow extension	Weakness = Triceps or nerve/root lesion
Reflexes		
C5	Biceps	Hypoactive/absence indicates radiculopathy
C6	Brachioradialis	Hypoactive/absence indicates radiculopathy
C7	Triceps	Hypoactive/absence indicates radiculopathy
Pulses: brachial, radial, ulnar		
SPECIAL TESTS		
Tennis elbow	Make fist, pronate, extend wrist and fingers against resistance	Pain at lateral epicondyle suggests lateral epicondylitis
Golfer's elbow	Supinate arm, extend wrist and elbow	Pain at medial epicondyle suggests medial epicondylitis
Ligament instability	25° flexion, apply varus/valgus stress	Pain or laxity indicates LCL/MCL injury
Pivot shift (PLRI)	Supine, extend elbow, flex shoulder above head. Supinate, axial load, valgus and flex elbow	Apprehension, palpable subluxation of radial head, or dimpling of skin over radial head positive test for posterolateral rotatory instability (PLRI)
Tinel's sign	Tap on ulnar groove (nerve)	Tingling in ulnar distribution indicates entrapment
Elbow flexion	Maximal elbow flexion for 3 min	Tingling in ulnar distribution indicates entrapment
Pinch grip	Pinch tips of thumb and index finger	Inability (or pinching of pads, not tips): AIN pathology


Posterior view
Deltoid muscle
Supraspinatus muscle
Infraspinatus muscle
Teres minor muscle
Triceps brachii muscle (lateral head)
Triceps brachii muscle (long head)
Deltoid muscle
Brachialis muscle
Triceps brachii muscle (medial head)
Common extensor tendon
Common flexor tendon
Anconeus muscle
Triceps brachii muscle
Anterior view
Trapezius muscle
Deltoid muscle
Biceps brachii muscle (long head)
Supraspinatus muscle
Subscapularis muscle
Pectoralis major muscle
Latissimus dorsi muscle
Teres major muscle
Deltoid muscle
Brachioradialis muscle
Extensor carpi radialis longus muscle
Common extensor tendon (extensor carpi radialis brevis, extensor digitorum with extensor digiti minimi and extensor carpi ulnaris muscles)
Brachialis muscle
Supinator muscle
Biceps brachii muscle
Coracobrachialis muscle and Biceps brachii muscle (short head)
Triceps brachii muscle (long head)
Coracobrachialis muscle
Brachialis muscle
Pronator teres muscle (humeral head)
Common flexor tendon (flexor carpi radialis, palmaris longus, flexor carpi ulnaris and flexor digitorum superficialis [humeroulnar head] muscles)
Flexor digitorum superficialis muscle (humeroulnar head)
Pronator teres muscle (ulnar head)
Flexor pollicis longus muscle (ulnar head)
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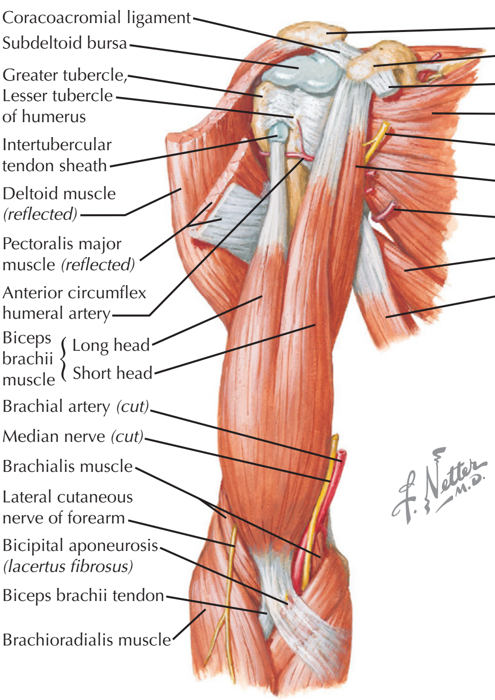
Muscle attachments
🟥 Origins
🟦 Insertions

CORACOID PROCESS	GREATER TUBEROSITY	ANTERIOR PROXIMAL HUMERUS	MEDIAL EPICONDYLE	LATERAL EPICONDYLE
ORIGINS				
Biceps (SH) Coracobrachialis			Pronator teres Common flex. tendon (FCR, PL, FCU, FDS)	Anconeus Common extensor tendon (ECRB, EDC, EDQ, ECU)
INSERTIONS				
Pectoralis minor	Supraspinatus Infraspinatus Teres minor	Pectoralis major Latissimus dorsi Teres major		

MUSCLES: ANTERIOR


Coracoacromial ligament
Subdeltoid bursa
Greater tubercle,
Lesser tubercle
of humerus
Intertubercular
tendon sheath
Deltoid muscle
(reflected)
Pectoralis major
muscle *(reflected)*
Anterior circumflex
humeral artery
Biceps brachii muscle
Long head
Short head
Brachial artery *(cut)*
Median nerve *(cut)*
Brachialis muscle
Lateral cutaneous
nerve of forearm
Bicipital aponeurosis
(lacertus fibrosus)
Biceps brachii tendon
Brachioradialis muscle
Acromion
Coracoid process
Pectoralis minor tendon *(cut)*
Subscapularis muscle
Musculocutaneous nerve *(cut)*
Coracobrachialis muscle
Circumflex scapular artery *(cut)*
Teres major muscle
Latissimus dorsi muscle
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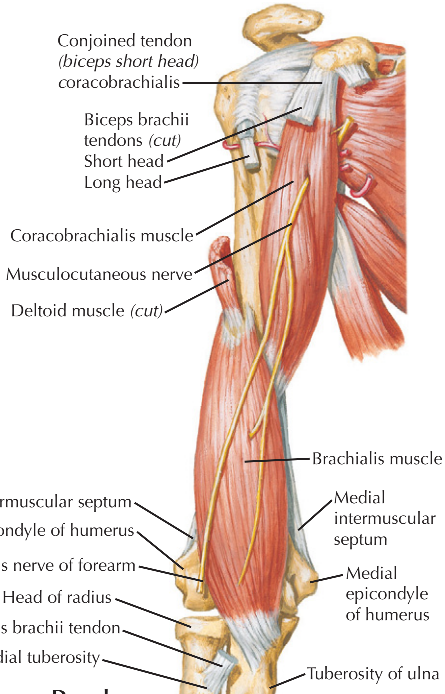
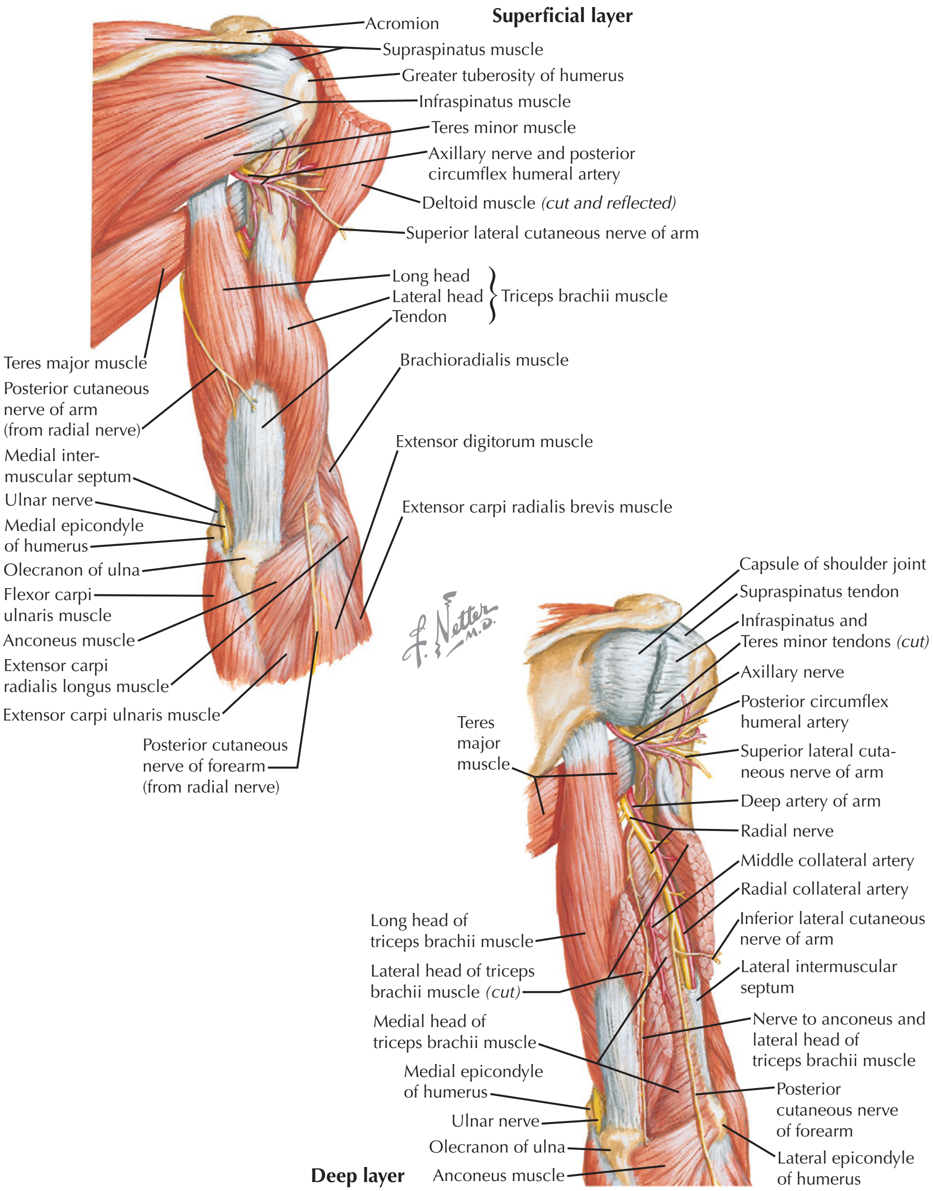
Superficial layer


Conjoined tendon
(biceps short head)
coracobrachialis
Biceps brachii
tendons *(cut)*
Short head
Long head
Coracobrachialis muscle
Musculocutaneous nerve
Deltoid muscle *(cut)*
Brachialis muscle
Lateral intermuscular septum
Lateral epicondyle of humerus
Lateral cutaneous nerve of forearm
Head of radius
Biceps brachii tendon
Radial tuberosity
Medial
intermuscular
septum
Medial
epicondyle
of humerus
Tuberosity of ulna

Deep layer

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
Coracobrachialis	Coracoid process	Middle humerus	Musculocutaneous	Flex and adduct arm	Part of "conjoined" tendon
Brachialis	Distal anterior humerus	Ulnar tuberosity (proximal ulna)	Medial: MSC n. Lateral: Radial n.	Flex forearm	Split in anterior surgical approach
Biceps brachii					
Long head	Supraglenoid tubercle	Radial tuberosity (proximal radius)	Musculocutaneous	Supinate and flex forearm	Rupture, results in "Popeye arm"
Short head	Coracoid process	Radial tuberosity (proximal radius)	Musculocutaneous	Supinate and flex forearm	Part of "conjoined" tendon



Superficial layer

Acromion
Supraspinatus muscle
Greater tuberosity of humerus
Infraspinatus muscle
Teres minor muscle
Axillary nerve and posterior circumflex humeral artery
Deltoid muscle (cut and reflected)
Superior lateral cutaneous nerve of arm
Long head
Lateral head
Tendon
Triceps brachii muscle
Brachioradialis muscle
Extensor digitorum muscle
Extensor carpi radialis brevis muscle
Teres major muscle
Posterior cutaneous nerve of arm (from radial nerve)
Medial inter-muscular septum
Ulnar nerve
Medial epicondyle of humerus
Olecranon of ulna
Flexor carpi ulnaris muscle
Anconeus muscle
Extensor carpi radialis longus muscle
Extensor carpi ulnaris muscle
Posterior cutaneous nerve of forearm (from radial nerve)
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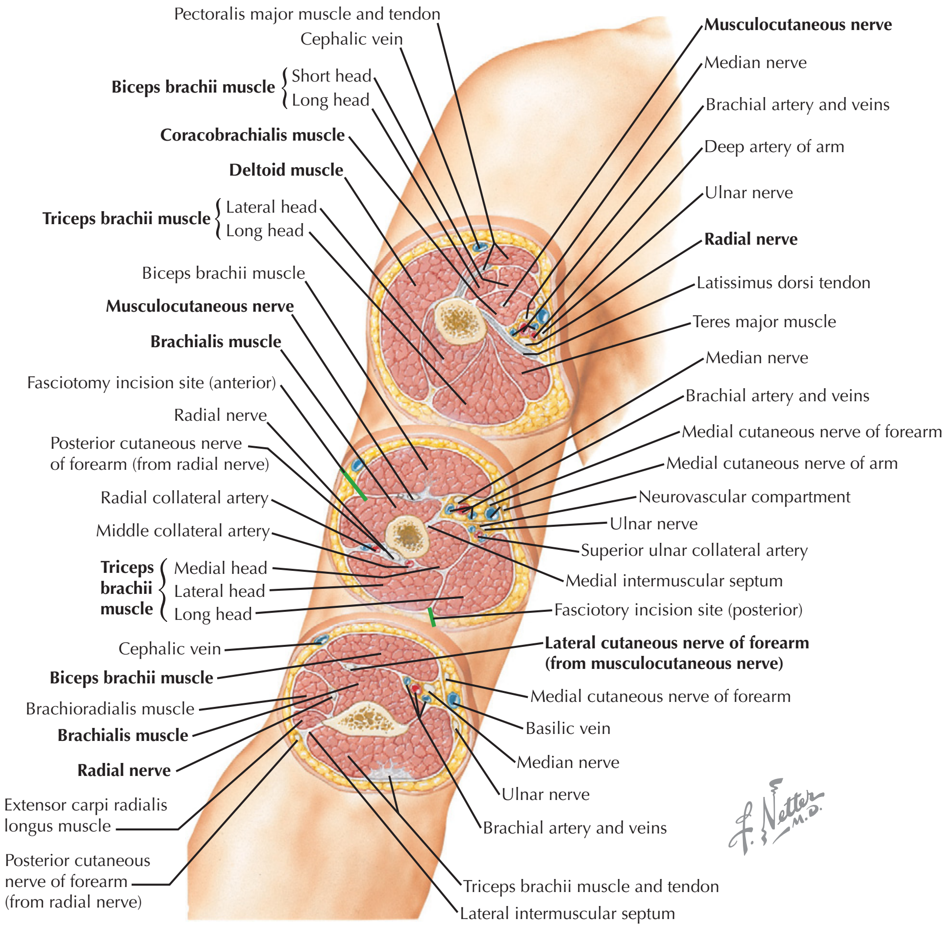
Deep layer

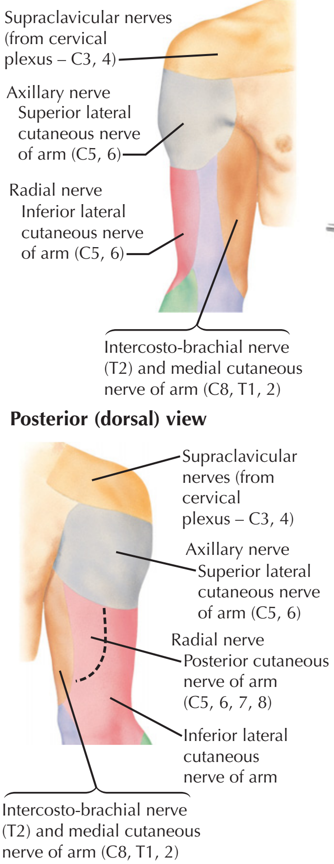
Capsule of shoulder joint
Supraspinatus tendon
Infraspinatus and Teres minor tendons (cut)
Axillary nerve
Posterior circumflex humeral artery
Superior lateral cutaneous nerve of arm
Deep artery of arm
Radial nerve
Middle collateral artery
Radial collateral artery
Inferior lateral cutaneous nerve of arm
Lateral intermuscular septum
Nerve to anconeus and lateral head of triceps brachii muscle
Posterior cutaneous nerve of forearm
Lateral epicondyle of humerus
Teres major muscle
Long head of triceps brachii muscle
Lateral head of triceps brachii muscle (cut)
Medial head of triceps brachii muscle
Medial epicondyle of humerus
Ulnar nerve
Olecranon of ulna
Anconeus muscle

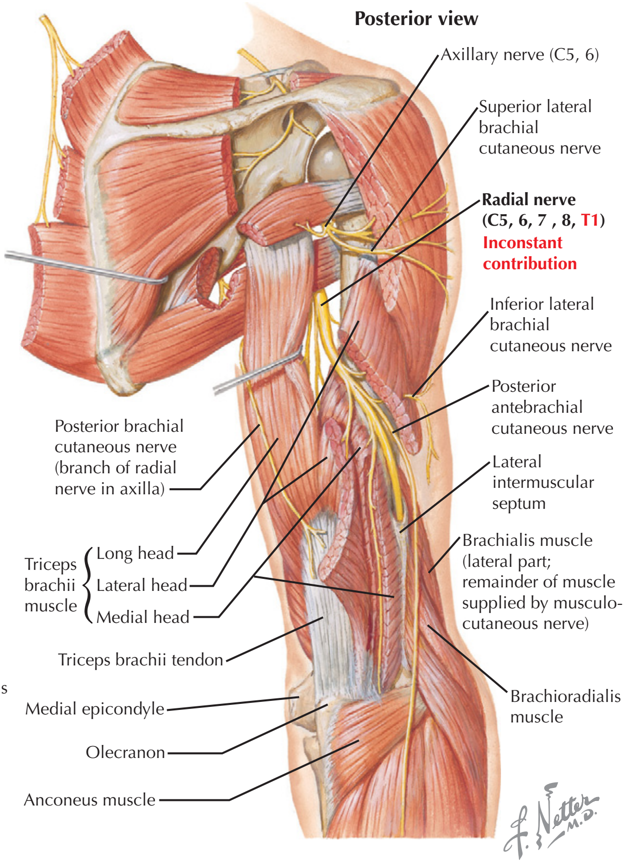
MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
Triceps brachii					
Long head	Infraglenoid tubercle	Olecranon	Radial nerve	Extends elbow	Border of quadrangular & triangular space & interval
Lateral head	Posterior humerus (proximal)	Olecranon	Radial nerve	Extends elbow	Border in lateral approach
Medial head	Posterior humerus (distal)	Olecranon	Radial nerve	Extends elbow	One muscular plane in posterior approach


Pectoralis major muscle and tendon
Cephalic vein
Biceps brachii muscle
Short head
Long head
Coracobrachialis muscle
Deltoid muscle
Triceps brachii muscle
Lateral head
Long head
Biceps brachii muscle
Musculocutaneous nerve
Brachialis muscle
Fasciotomy incision site (anterior)
Radial nerve
Posterior cutaneous nerve of forearm (from radial nerve)
Radial collateral artery
Middle collateral artery
Triceps brachii muscle
Medial head
Lateral head
Long head
Cephalic vein
Biceps brachii muscle
Brachioradialis muscle
Brachialis muscle
Radial nerve
Extensor carpi radialis longus muscle
Posterior cutaneous nerve of forearm (from radial nerve)
Musculocutaneous nerve
Median nerve
Brachial artery and veins
Deep artery of arm
Ulnar nerve
Radial nerve
Latissimus dorsi tendon
Teres major muscle
Median nerve
Brachial artery and veins
Medial cutaneous nerve of forearm
Medial cutaneous nerve of arm
Neurovascular compartment
Ulnar nerve
Superior ulnar collateral artery
Medial intermuscular septum
Fasciotory incision site (posterior)
Lateral cutaneous nerve of forearm (from musculocutaneous nerve)
Medial cutaneous nerve of forearm
Basilic vein
Median nerve
Ulnar nerve
Brachial artery and veins
Triceps brachii muscle and tendon
Lateral intermuscular septum
F. Netter M.D.

STRUCTURE	RELATIONSHIP
	RELATIONSHIPS
Musculocutaneous n.	Pierces coracobrachialis 8cm distal to coracoid, then lies b/w the biceps and brachialis muscles where lateral antebrachial cutaneous nerve (terminal branch) emerges
Radial n.	Starts medial, then spirals posteriorly and laterally around humerus (in spiral groove) and emerges b/w brachialis and brachioradialis muscles in distal lateral arm
Ulnar n.	In medial arm, from anterior to posterior compartment (across IM septum) into cubital tunnel
Median n.	In anteromedial arm, initially lateral to brachial artery, but crosses over it to become medial
Brachial artery	Runs with median nerve, then crosses under it to become more midline in distal arm/elbow
	COMPARTMENTS
Anterior	Muscles: brachialis, biceps brachii, coracobrachialis Neurovascular: musculocutaneous nerve, median nerve, brachial artery, radial nerve (distally)
Posterior	Muscles: triceps brachii Neurovascular: radial nerve (mid arm), ulnar nerve (distal arm), radial recurrent arteries

Cutaneous Innervation


Anterior (palmar) view
Supraclavicular nerves (from cervical plexus – C3, 4)
Axillary nerve
Superior lateral cutaneous nerve of arm (C5, 6)
Radial nerve
Inferior lateral cutaneous nerve of arm (C5, 6)
Intercosto-brachial nerve (T2) and medial cutaneous nerve of arm (C8, T1, 2)
Posterior (dorsal) view
Supraclavicular nerves (from cervical plexus – C3, 4)
Axillary nerve
Superior lateral cutaneous nerve of arm (C5, 6)
Radial nerve
Posterior cutaneous nerve of arm (C5, 6, 7, 8)
Inferior lateral cutaneous nerve of arm
Intercosto-brachial nerve (T2) and medial cutaneous nerve of arm (C8, T1, 2)


Posterior view
Axillary nerve (C5, 6)
Superior lateral brachial cutaneous nerve
Radial nerve (C5, 6, 7 , 8, T1)
Inconstant contribution
Inferior lateral brachial cutaneous nerve
Posterior antebrachial cutaneous nerve
Lateral intermuscular septum
Brachialis muscle (lateral part; remainder of muscle supplied by musculo-cutaneous nerve)
Brachioradialis muscle
Posterior brachial cutaneous nerve (branch of radial nerve in axilla)
Triceps brachii muscle
Long head
Lateral head
Medial head
Triceps brachii tendon
Medial epicondyle
Olecranon
Anconeus muscle

BRACHIAL PLEXUS

Lateral and Medial Cord

Median (C[5]6-T1): runs in medial arm (anterior compartment), medial to biceps and brachialis (lateral to brachial artery), then crosses over (medial) to artery and enters forearm under biceps aponeurosis (lacertus fibrosus)

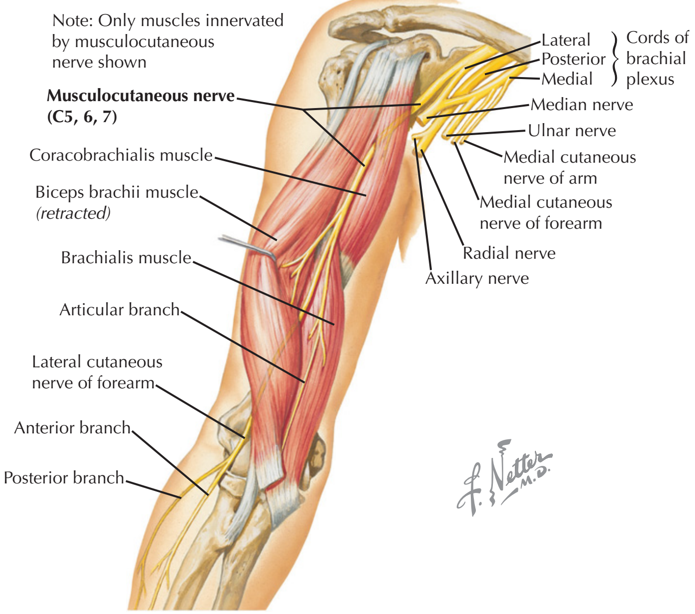
Sensory: None (in arm, see Hand chapter)
Motor: None (in arm, see Forearm & Hand chapters)

Posterior Cord

Radial (C5-T1): starts medial to humerus, crosses posterior into spiral groove (where it can be entrapped in a humerus fracture, esp. distal ⅓ fractures) with deep artery of the arm, then exits between the brachioradialis & brachialis, then divides into deep (motor–PIN) and superficial (sensory) branches

Sensory: Posterior arm: via **posterior cutaneous n. of arm** (posterior brachial cutaneous)
Lateral arm: via **inferior lateral cutaneous n. of arm**

Motor:
- Posterior compartment
  - Triceps brachii
- Anterior compartment
  - Brachialis (lateral portion)


Musculocutaneous nerve (C5, 6, 7)
Coracobrachialis muscle
Biceps brachii muscle (retracted)
Brachialis muscle
Articular branch
Lateral cutaneous nerve of forearm
Anterior branch
Posterior branch
Lateral
Posterior
Medial
Cords of brachial plexus
Median nerve
Ulnar nerve
Medial cutaneous nerve of arm
Medial cutaneous nerve of forearm
Radial nerve
Axillary nerve
F. Netter M.D.

Anterior view

Note: Only muscles innervated by musculocutaneous nerve shown

BRACHIAL PLEXUS

Lateral Cord

Musculocutaneous (C5-7): pierces coracobrachialis (6-8cm below coracoid, where it is at risk from retraction of the conjoined tendon), then runs between the biceps & brachialis, innervating both. Sensory terminal branch exits between the biceps & brachialis at elbow.

Sensory: None (in arm, see Forearm chapter)

Motor:
- Anterior compartment
    - Coracobrachialis
    - Biceps brachii
    - Brachialis (medial portion)

Medial Cord

Medial cutaneous n. of arm (brachial cutaneous [C8-T1]): branches from the cord, joins intercostobrachial nerve, and runs subcutaneously in the medial arm.

Sensory: Medial arm

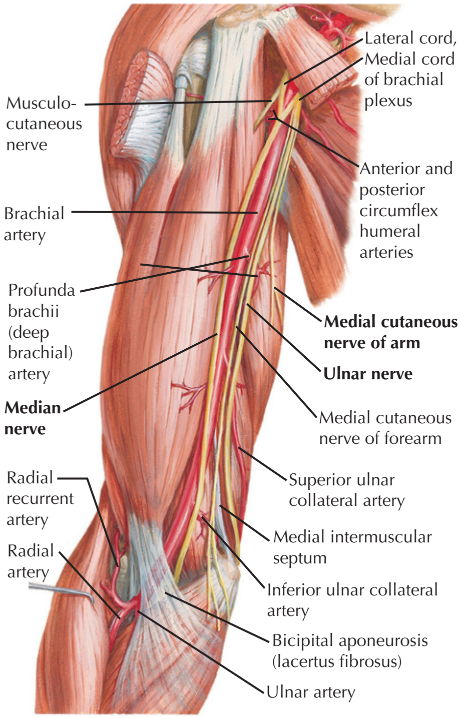
Motor: None

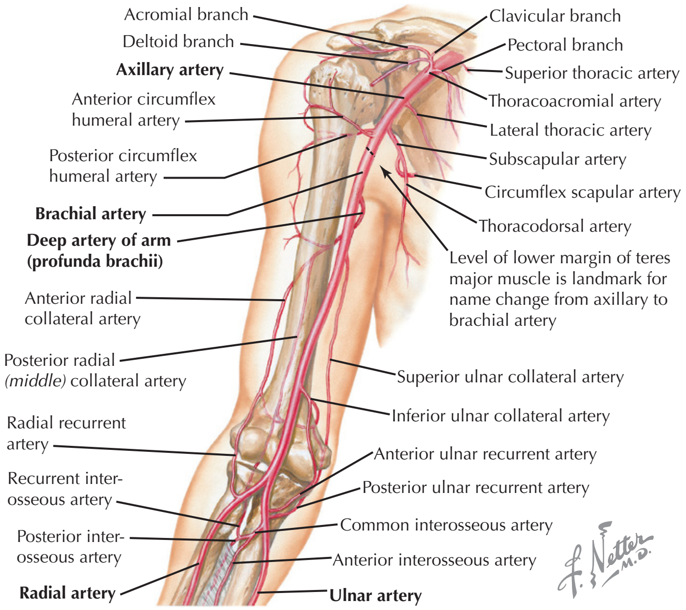
Ulnar (C[7]8-T1): runs from anterior to posterior compartment in medial arm over the IM septum, then under the arcade of Struthers onto the triceps (medial head), then into cubital tunnel posterior to the medial epicondyle

Sensory: None (in arm, see Forearm & Hand)

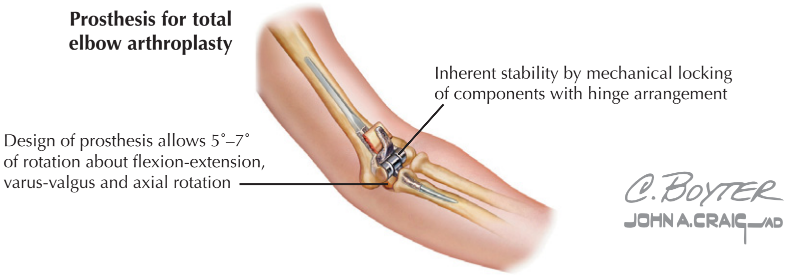
Motor: None (in arm, see Forearm & Hand)

Nerves of the arm
Anterior view


Lateral cord, Medial cord of brachial plexus
Musculocutaneous nerve
Anterior and posterior circumflex humeral arteries
Brachial artery
Profunda brachii (deep brachial) artery
Medial cutaneous nerve of arm
Ulnar nerve
Median nerve
Medial cutaneous nerve of forearm
Radial recurrent artery
Superior ulnar collateral artery
Medial intermuscular septum
Radial artery
Inferior ulnar collateral artery
Bicipital aponeurosis (lacertus fibrosus)
Ulnar artery


Acromial branch
Deltoid branch
Axillary artery
Anterior circumflex humeral artery
Posterior circumflex humeral artery
Brachial artery
Deep artery of arm (profunda brachii)
Anterior radial collateral artery
Posterior radial *(middle)* collateral artery
Radial recurrent artery
Recurrent interosseous artery
Posterior interosseous artery
Radial artery
Clavicular branch
Pectoral branch
Superior thoracic artery
Thoracoacromial artery
Lateral thoracic artery
Subscapular artery
Circumflex scapular artery
Thoracodorsal artery
Level of lower margin of teres major muscle is landmark for name change from axillary to brachial artery
Superior ulnar collateral artery
Inferior ulnar collateral artery
Anterior ulnar recurrent artery
Posterior ulnar recurrent artery
Common interosseous artery
Anterior interosseous artery
Ulnar artery

BRANCHES	**COURSE**	**COMMENT/SUPPLY**
BRACHIAL ARTERY		
The continuation of the axillary artery. It runs with the median n., then crosses under the nerve to be midline.		
Deep artery (profunda brachii)	In the spiral groove	Runs with the radial nerve, can be injured there
Nutrient humeral artery	Enters the nutrient canal	Supplies the humerus
Superior ulnar collateral	With ulnar n. in medial arm	Anastomosis with posterior ulnar recurrent artery
Inferior ulnar collateral	Branches in distal arm	Anastomosis with anterior ulnar recurrent artery
Muscular branches	Usually branch laterally	Supply musculature of the arm
Radial	Terminal branch	One of 2 terminal branches
Ulnar	Terminal branch	One of 2 terminal branches
DEEP ARTERY		
Anterior radial collateral	In anterolateral arm	Anastomosis with radial recurrent artery
Posterior (middle) radial collateral	Posterior to humerus	Anastomosis with recurrent interosseous artery Used as pedicle in lateral arm flap
RADIAL ARTERY		
Radial recurrent	Runs in anterolateral portion of the arm	Anastomosis with anterior radial collateral artery Branches (leash of Henry) can compress radial n.
ULNAR ARTERY		
Anterior ulnar recurrent	In anteromedial arm	Anastomosis with inferior ulnar collateral artery
Posterior ulnar recurrent	In posteromedial arm	Anastomosis with superior ulnar collateral artery
Common interosseous	Midline branch	Is a trunk with multiple branches
Recurrent interosseous	Posterior to elbow	Anastomosis w/ post. radial (middle) collateral artery
Anterior & posterior interosseous	Along intermuscular septum	Supplies forearm musculature

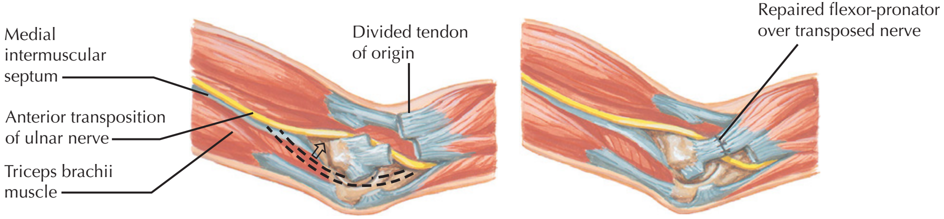


Prosthesis for total elbow arthroplasty

Inherent stability by mechanical locking of components with hinge arrangement
Design of prosthesis allows 5°–7° of rotation about flexion-extension, varus-valgus and axial rotation
C. Boyter
JOHN A.CRAIG—MD

Three types of total elbow arthroplasty have been used. Results were better with an unrestrained prosthesis but with 5%–20% incidence of postoperative instability, most patients are now treated with a semi-constrained prosthesis, which has inherent stability by linking of the component usually with a hinge (shown above) or a snap-fit axis arrangement.

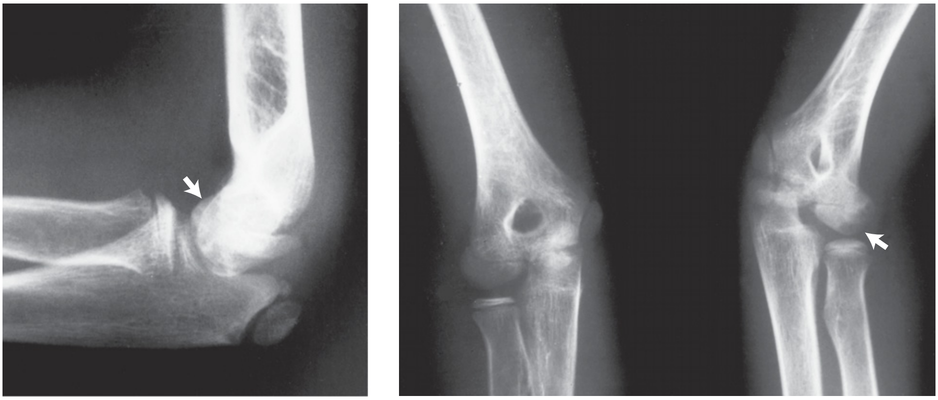
Submuscular tranposition of ulnar nerve



Medial intermuscular septum
Anterior transposition of ulnar nerve
Triceps brachii muscle
Divided tendon of origin
Repaired flexor-pronator over transposed nerve

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
ARTHRITIS			
• Less common condition • Osteoarthritis seen in athletes/laborers • Site for arthritides (RA, gout, etc)	**Hx:** Chronic pain, stiffness, +/− previous trauma **PE:** Decreased ROM & tenderness (especially in extension)	• **XR:** OA vs inflammatory • **Blood:** RF, ESR, ANA • **Joint fluid:** crystals, cells, culture	1. Conservative (rest, NSAID) 2. Debridement (osteophytes, loose bodies) 3. Ulnohumeral arthroplasty 4. Total elbow arthroplasty
CUBITAL TUNNEL SYNDROME			
• Entrapment of ulnar nerve at elbow • Sites: ◦ IM septum ◦ Arcade of Struthers ◦ Cubital tunnel ◦ FCU fascia	**Hx:** Numbness/tingling in ulnar distribution, +/− elbow pain **PE:** +/− decreased grip strength, intrinsic atrophy, + Tinel's and/or elbow flexion text	**XR:** Look for abnormal medial epicondyle **EMG:** Confirms diagnosis	1. Rest, ice, NSAIDs, activity modification 2. Splints (day and/or night) 3. Ulnar nerve transposition (submuscular vs subcutaneous)
LATERAL EPICONDYLITIS (TENNIS ELBOW)			
• Degenerative of common extensor tendons (esp. ECRB) • Due to overuse (e.g., tennis) and/or injury (microtrauma) to tendon	**Hx:** Age 30-60, chronic pain at lateral elbow, worse w/wrist extension **PE:** Lateral epicondyle TTP; pain with resisted wrist extension	**XR:** Rule out fracture & OA. Calcification of tendons can occur (esp. ECRB)	1. Activity modification, NSAIDs 2. Use of brace/strap 3. Stretching/strengthening 4. Corticosteroid injection 5. Surgical debridement of tendon (ECRB #1)
OLECRANON BURSITIS			
• Inflammation of bursa (infection/trauma/other)	**Hx:** Swelling, acute or chronic pain **PE:** Palpable/fluctuant mass at olecranon	**LAB:** Aspirate bursa, send fluid for culture, cell count, Gram stain and crystals	1. Compressive dressing 2. Activity modification 3. Corticosteroid injection 4. Surgical debridement

Osteochondral lesion of the capitellum

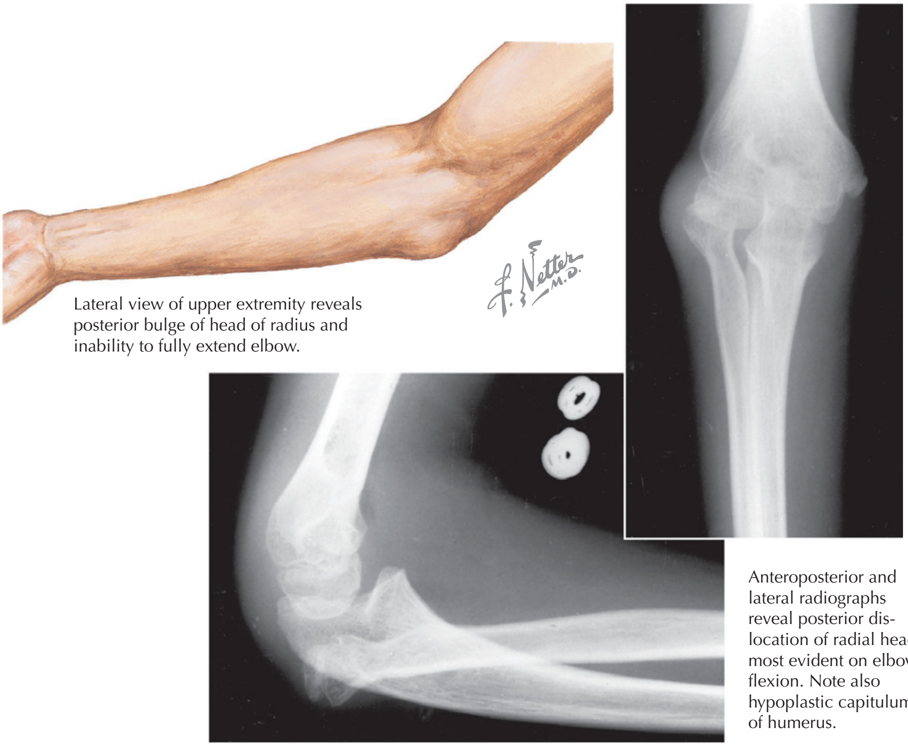


Bone resorption seen as radiolucent areas and irregular surface of capitellum of humerus

Characteristic changes in capitellum of left humerus (arrow) compared with normal right elbow

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
DISTAL BICEPS TENDON RUPTURE			
• Mechanism: eccentric overload of partially flexed elbow • Usually male 40-60 y.o. • Early diagnosis important	**Hx:** Acute injury/"pop" **PE:** No palpable tendon, weak and/or painful flexion & supination	**XR:** Usually normal **MR:** Can confirm diagnosis but usually not needed	1. Early: primary repair (1 or 2 incision techniques) 2. Late: no surgery; physical therapy
MEDIAL ELBOW INSTABILITY			
• MCL (anterior bundle) injury from repetitive valgus stress • Acute or chronic, associated with throwers (baseball, javelin)	**Hx:** Pain with throwing or inability to throw **PE:** MCL tenderness, +/− valgus laxity (at >30°)	**XR:** Stress view may show widening (usu. dynamic) postmedial osteophytes. **MR:** Avulsion and tears	1. Rest, activity modification 2. Physical therapy (ROM) 3. Ligament reconstruction & debridement of osteophytes/loose bodies
OSTEOCHONDRITIS DISSECANS OF ELBOW			
• Vascular insufficiency or microtrauma to capitellum • Adolescent throwers/gymnasts with valgus/compressive loads	**Hx:** Lateral elbow pain, +/− catching, stiffness **PE:** Capitellum TTP, pain w/ valgus stress	**XR:** Lucency, +/− fragmentation of the capitellum **CT:** Helpful to identify loose bodies	1. Rest & physical therapy 2. ORIF of fragments or arthroscopic debridement of loose bodies & chondroplasty
POSTEROLATERAL ROTATORY INSTABILITY			
• Lateral ulnar collateral ligament (LUCL) injury • Allows radial head to subluxate • Mech: traumatic (elbow dx) or iatrogenic (elbow surgery)	**Hx:** Hx of trauma or surgery, pain, +/− clicking **PE:** + lateral pivot shift test (often needs EUA)	**XR:** Often normal **Stress XR:** Shows radial head subluxation **MR:** Identifies LUCL tear	1. Rest, activity modification 2. Physical therapy (ROM) 3. LUCL reconstruction (usually with a palmaris graft)
STIFF ELBOW			
• <30-120° • Intrinsic vs extrinsic etiology • Intrinsic: articular changes/ arthrosis (posttraumatic, etc) • Extrinsic: capsule contracture	**Hx:** Trauma, stiffness, minimal pain **PE:** Limited ROM (esp. in flexion and extension)	**XR:** AP/lateral/oblique Look for osteophytes or other signs of intrinsic joint arthrosis	1. Physical therapy: ROM 2. Operative: Intrinsic: excise osteophytes, LBs Extrinsic: capsular release

Congenital dislocation of radial head

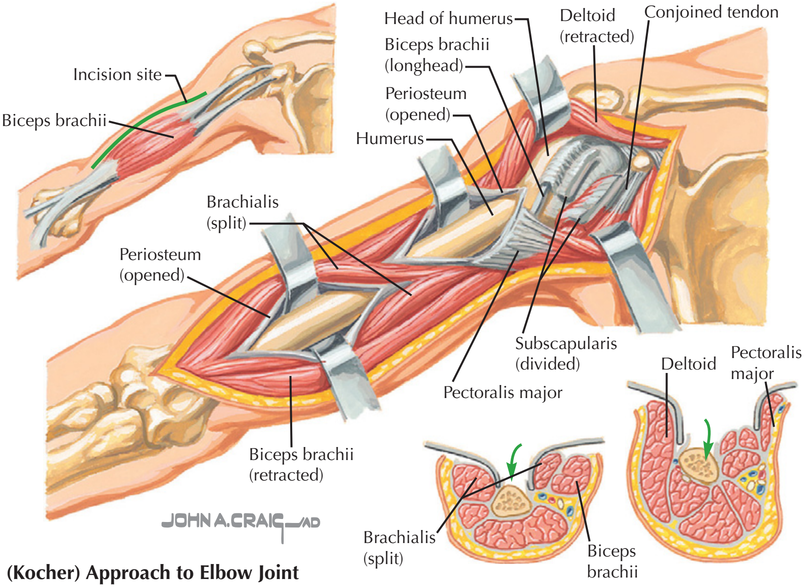


Lateral view of upper extremity reveals posterior bulge of head of radius and inability to fully extend elbow.

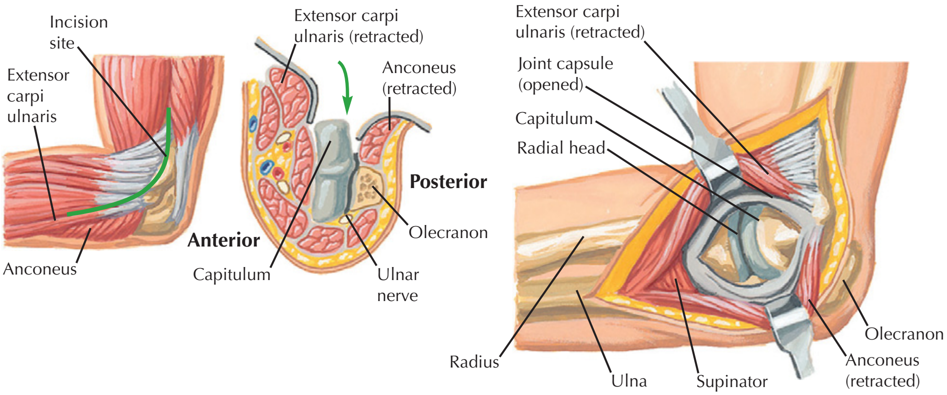
Anteroposterior and lateral radiographs reveal posterior dislocation of radial head, most evident on elbow flexion. Note also hypoplastic capitulum of humerus.

DESCRIPTION	EVALUATION	TREATMENT
CONGENITAL RADIAL HEAD DISLOCATION		
• Radial head congenitally dislocated • Usually diagnosed from 2-5y.o. • Patients are typically very functional • Unilateral or bilateral • Associated with other syndromes	**Hx:** Parents notice decreased ROM, +/− pain or deformity (late) **PE:** Decreased ROM, +/− visible radial head and/or tenderness **XR:** Malformed radial head & capitellum	• Asymptomatic: observation • Symptomatic (pain): excision of radial head at skeletal maturity (decreases pain, but does not typically increase ROM)
RADIOULNAR SYNOSTOSIS		
• Failure of separation of radius & ulna • Forearm rotation is absent • Can be assoc. with other syndromes • Bilateral in 60% of cases	**Hx/PE:** Absent pronosupination of the elbow/forearm. Varying degrees of fixed deformity (>60° is severe) **XR:** Radius is thickened, ulna is narrow	• Synostosis resection unsuccessful Mild/unilateral: observation • Osteotomy: dominant hand 20° of pronation, nondominant 30° of supination
OSTEOCHONDROSIS OF CAPITELLUM (PANNER'S DISEASE)		
• Disordered endochondral ossification • Mech: valgus (pitcher's) compression or axial overload (gymnasts) • Usually <10 y.o.; male>female • Favorable long-term prognosis	**Hx:** Insidious onset lateral elbow pain and overuse (baseball, gymnastics) **PE:** Capitellum TTP, decreased ROM **XR:** Irregular borders, +/− fissuring, fragmentation (rarely loose bodies)	1. Rest (no pitching, tumbling, etc) 2. NSAIDs 3. Immobilization (3-4 weeks) Symptoms may persist for months, but most completely resolve

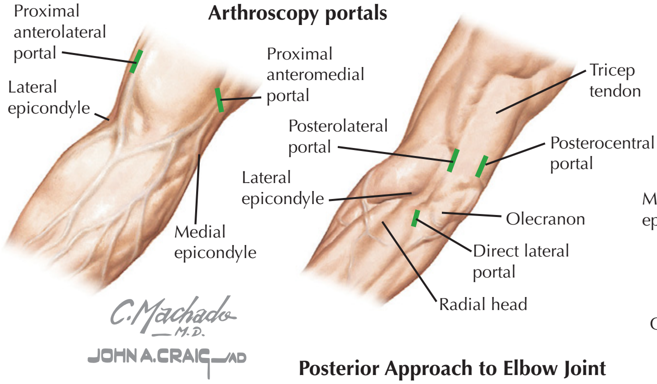
Anterolateral Approach to Humerus

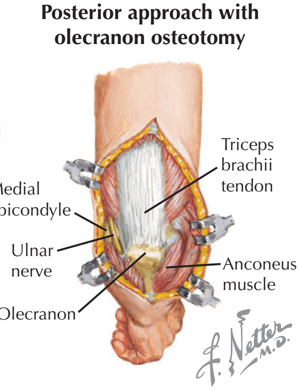

Incision site
Biceps brachii
Head of humerus
Biceps brachii (longhead)
Periosteum (opened)
Humerus
Deltoid (retracted)
Conjoined tendon
Brachialis (split)
Periosteum (opened)
Subscapularis (divided)
Pectoralis major
Biceps brachii (retracted)
JOHN A.CRAIG_AD
Deltoid
Pectoralis major
Brachialis (split)
Biceps brachii

Lateral (Kocher) Approach to Elbow Joint

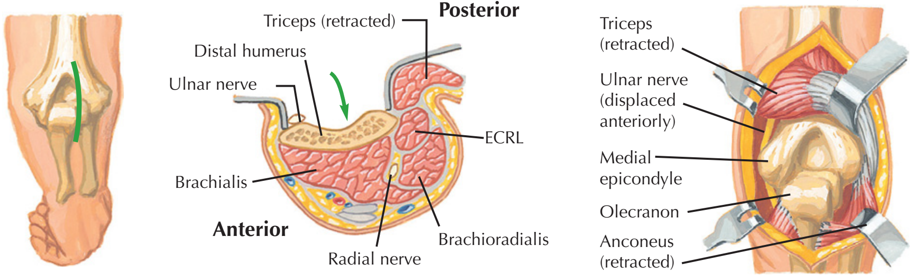

Incision site
Extensor carpi ulnaris
Anconeus
Extensor carpi ulnaris (retracted)
Anconeus (retracted)
Posterior
Anterior
Olecranon
Capitulum
Ulnar nerve
Extensor carpi ulnaris (retracted)
Joint capsule (opened)
Capitulum
Radial head
Radius
Ulna
Supinator
Olecranon
Anconeus (retracted)

USES	INTERNERVOUS PLANES	DANGERS	COMMENT
	HUMERUS: ANTERIOR APPROACH		
• ORIF of fractures • Bone biopsy/tumor removal	**Proximal** • Deltoid (axillary) • Pectoralis major (pectoral) **Distal** • Brachialis splitting ◦ Lateral (radial) ◦ Medial (MSC)	**Proximal** • Axillary nerve • Humeral circumflex artery **Distal** • Radial nerve • Musculocutaneous nerve	• Anterior humeral circumflex artery may need ligation. • The brachialis has a split innervation that can be used for an internervous plane.
	ELBOW: LATERAL APPROACH (KOCHER)		
Most radial head & lateral condyle procedures	• Anconeus (radial) • ECU (PIN)	• PIN • Radial nerve	• Protect PIN: stay above annular ligament; keep forearm pronated


Arthroscopy portals
Proximal anterolateral portal
Lateral epicondyle
Medial epicondyle
Proximal anteromedial portal
Tricep tendon
Posterolateral portal
Posterocentral portal
Lateral epicondyle
Olecranon
Direct lateral portal
Radial head
C. Machado M.D.
JOHN A. CRAIG MD


Posterior approach with olecranon osteotomy
Triceps brachii tendon
Medial epicondyle
Ulnar nerve
Anconeus muscle
Olecranon
F. Netter M.D.

Posterior Approach to Elbow Joint


Posterior
Triceps (retracted)
Distal humerus
Ulnar nerve
ECRL
Brachialis
Anterior
Radial nerve
Brachioradialis
Triceps (retracted)
Ulnar nerve (displaced anteriorly)
Medial epicondyle
Olecranon
Anconeus (retracted)

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
POSTERIOR APPROACH			
• Distal humerus fractures • Loose body removal, chondral procedures • Ulnohumeral arthroplasty • Total elbow arthroplasty	• No internervous plane • Olecranon is osteotomized and reflected to expose the distal humerus/joint.	• Ulnar nerve • Nonunion of olecranon osteotomy	• Best exposure of the joint • Olecranon should be drilled and tapped before osteotomy • Chevron osteotomy is best • Olecranon at risk of nonunion
POSTERIOR APPROACH: BRYAN/MORREY			
• Alternative to posterior approach with osteotomy • Same indications as above	• No internervous plane • Triceps is partially detached and reflected laterally	• Ulnar nerve	• Joint visualization is not as good as with osteotomy, no concern for nonunion
ARTHROSCOPY PORTALS			
Uses: Loose body removal/articular injuries, debridements and capsular release, fracture reduction, limited arthroplasty			
Proximal anteromedial	2cm prox. to med. epicondyle anterior to IM septum	Ulnar nerve MAC nerve	Anterior compartment, radial head & capitellum, capsule
Proximal anterolateral	2cm prox. to lat. epicondyle anterior to humerus	Radial nerve	Medial joint, lateral recess, and radiocapitellar joint
Posterocentral	3cm from olecranon tip	Safe (thru tendon)	Posterior compartment, gutters
Posterolateral	3cm from olecranon tip at lat. edge of triceps tendon	Med. & post. antebrachial cutaneous n.	Olecranon tip & fossa, posterior trochlea
Direct lateral ("soft spot")	Between lat. epicondyle, radial head & olecranon	Posterior antebrachial cutaneous nerve	Inferior capitellum and radiocapitellar joint

CHAPTER 5

Forearm

Topographic Anatomy 140
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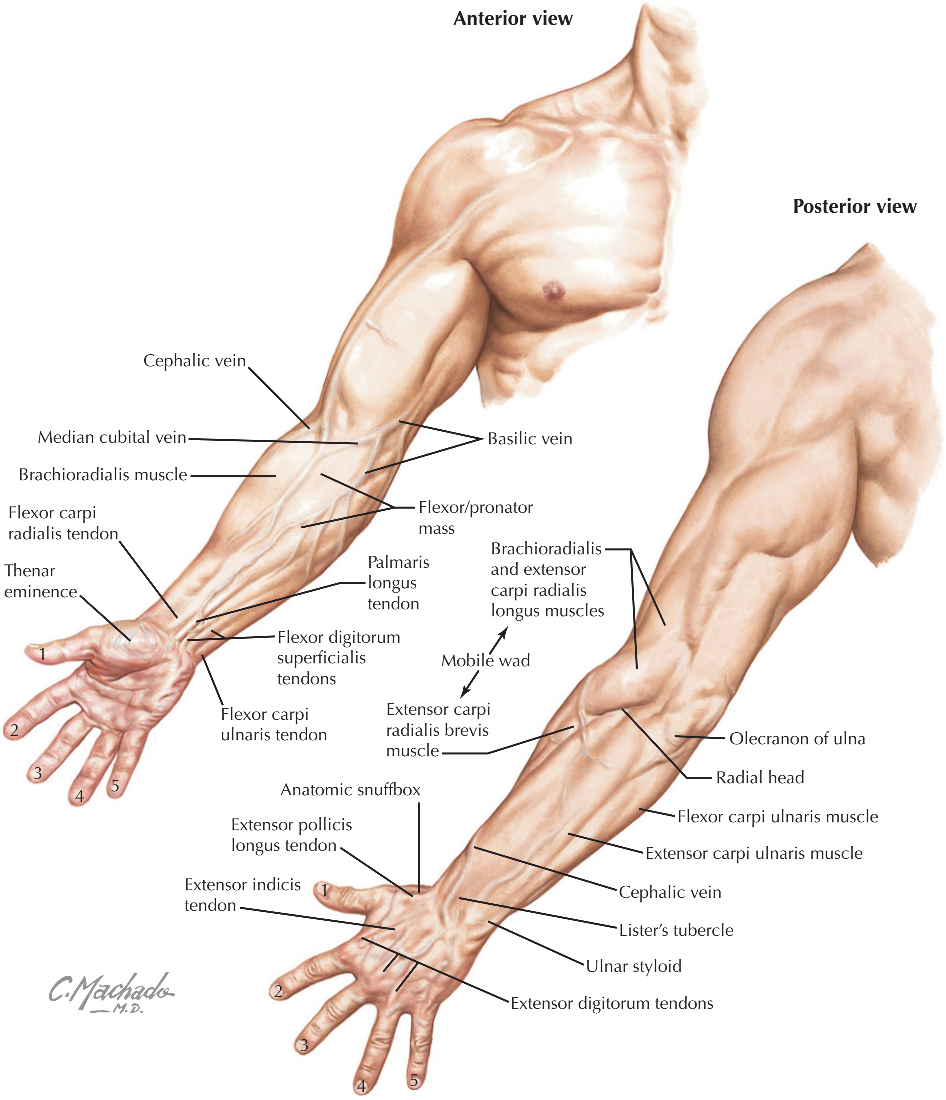
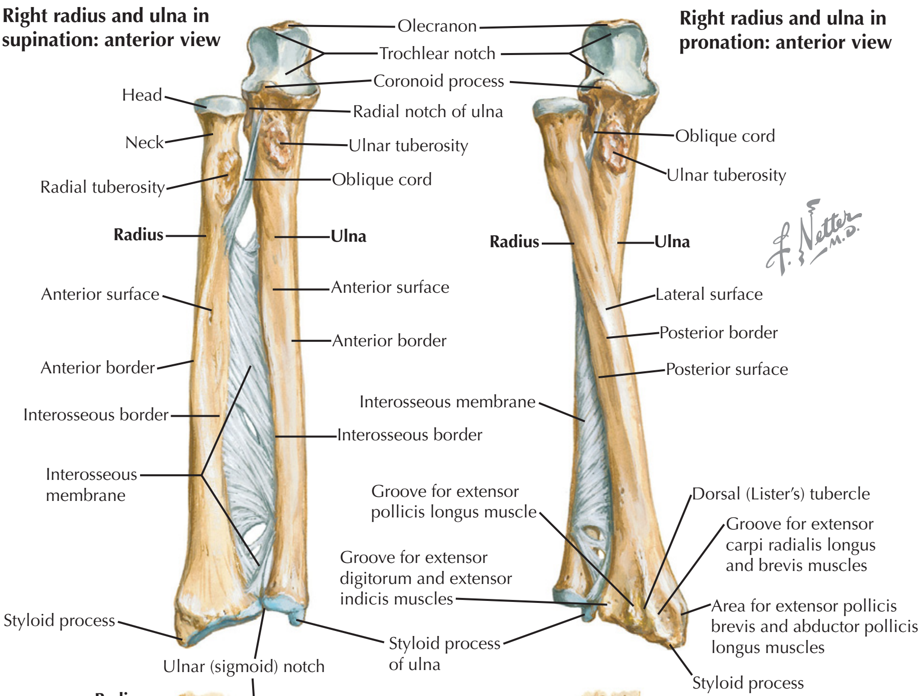
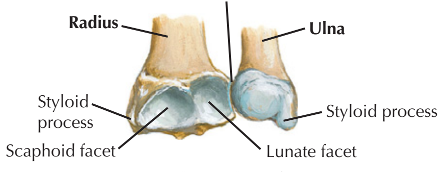

Anterior view
Posterior view
Cephalic vein
Median cubital vein
Brachioradialis muscle
Flexor carpi radialis tendon
Thenar eminence
Basilic vein
Flexor/pronator mass
Palmaris longus tendon
Flexor digitorum superficialis tendons
Flexor carpi ulnaris tendon
1
2
3
4
5
Brachioradialis and extensor carpi radialis longus muscles
Mobile wad
Extensor carpi radialis brevis muscle
Anatomic snuffbox
Extensor pollicis longus tendon
Extensor indicis tendon
Olecranon of ulna
Radial head
Flexor carpi ulnaris muscle
Extensor carpi ulnaris muscle
Cephalic vein
Lister's tubercle
Ulnar styloid
Extensor digitorum tendons
C.Machado M.D.

STRUCTURE	CLINICAL APPLICATION
Olecranon	Proximal tip of ulna. Tenderness can indicate fracture.
Radial head	Proximal end of radius. Tenderness can indicate fracture.
Flexor radialis tendon	Landmark for volar approach to wrist. Radial pulse is just radial to tendon.
Lister's tubercle	Tubercle on dorsal radius. "Lighthouse of the wrist." EPL tendon runs around it.
Ulnar styloid	Prominent distal end of ulna. Tenderness can indicate fracture.
Palmaris longus tendon	Not present in all people. Can be used for tendon grafts.
Anatomic snuffbox	Site of scaphoid. Tenderness can indicate a scaphoid fracture.

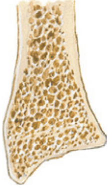

Right radius and ulna in supination: anterior view

Right radius and ulna in pronation: anterior view

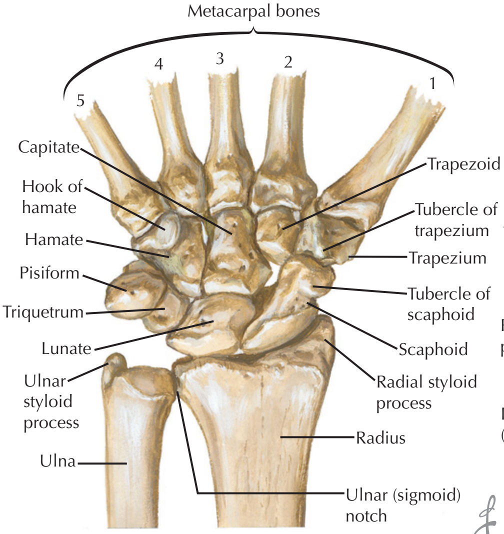
Olecranon
Trochlear notch
Coronoid process
Head
Radial notch of ulna
Neck
Ulnar tuberosity
Radial tuberosity
Oblique cord
Radius
Ulna
Anterior surface
Anterior surface
Anterior border
Anterior border
Interosseous border
Interosseous membrane
Interosseous border
Interosseous membrane
Styloid process
Ulnar (sigmoid) notch
Oblique cord
Ulnar tuberosity
Radius
Ulna
F. Netter M.D.
Lateral surface
Posterior border
Posterior surface
Interosseous membrane
Groove for extensor pollicis longus muscle
Dorsal (Lister's) tubercle
Groove for extensor carpi radialis longus and brevis muscles
Groove for extensor digitorum and extensor indicis muscles
Area for extensor pollicis brevis and abductor pollicis longus muscles
Styloid process of ulna
Styloid process


Radius
Ulna
Styloid process
Styloid process
Scaphoid facet
Lunate facet

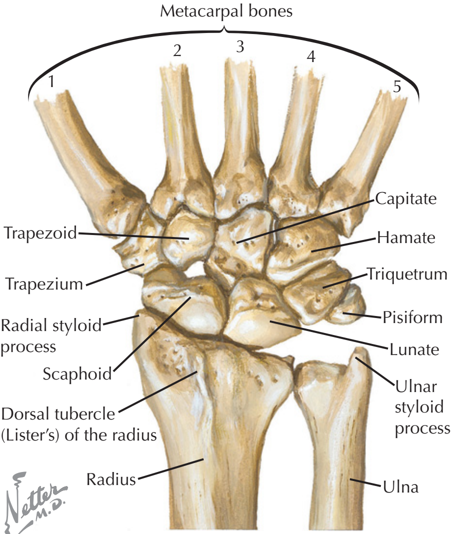
Carpal articular suface


Coronal section of radius demonstrates how thickness of cortical bone of shaft diminishes to thin layer over cancellous bone at distal end

CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
RADIUS				
• Cylindrical long bone • Head is intraarticular • Tuberosity: biceps inserts • Shaft has a bow • Distal end widens, is made of cancellous bone, has scaphoid & lunate facets, & radial styloid • Ulnar (sigmoid) notch: DRUJ	**Primary**			• Anterolateral portion of RH has less subchondral bone (susceptible to fracture) • Tuberosity points ulnarly in supination • Bow allows rotation around ulna • Cancellous distal radius common fracture site (esp. in peds & older pts) • Distal radius x-ray measurements: 11° volar tilt, 22° radial inclination, 11-12mm radial height
	Shaft	8-9wk	14yr	
	Secondary			
	Head	2-3yr	16-18yr	
	Distal epiphysis	4yr	16-18yr	
ULNA				
• Long bone: straight bone • Triangular cross-section • Tuberosity: brachialis insertion • Proximal: olecranon, coronoid process, radial (sigmoid) notch • Distal: ulnar styloid	**Primary**			• The radius rotates around the stationary ulna through proximal & distal notches during pronation/supination • 75% of growth from distal epiphysis • Olecranon & coronoid provide primary bony stability to elbow joint • Coronoid fx can result in instability • Common site of fx (often w/DR fx)
	Shaft	8-9wk	16-18yr	
	Secondary			
	Olecranon	9yr	16-20yr	
	Distal epiphysis	5-6yr	16-20yr	


Metacarpal bones
5
4
3
2
1
Capitate
Hook of hamate
Hamate
Pisiform
Triquetrum
Lunate
Ulnar styloid process
Ulna
Trapezoid
Tubercle of trapezium
Trapezium
Tubercle of scaphoid
Scaphoid
Radial styloid process
Radius
Ulnar (sigmoid) notch

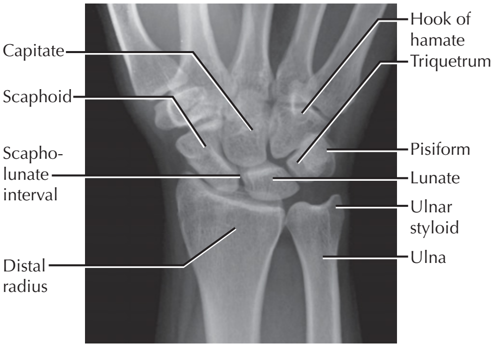
Anterior (palmar) view


Metacarpal bones
1
2
3
4
5
Trapezoid
Trapezium
Radial styloid process
Scaphoid
Dorsal tubercle (Lister's) of the radius
Radius
Capitate
Hamate
Triquetrum
Pisiform
Lunate
Ulnar styloid process
Ulna

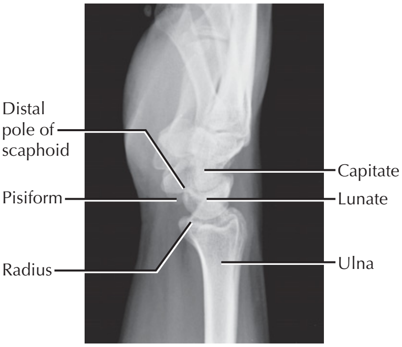
Posterior (dorsal) view

CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
PROXIMAL ROW				
Scaphoid: boat shape, 80% covered with articular cartilage (not waist)	5th	5yr	14-16yr	• Blood supply enters dorsal waist, bridges both rows • #1 carpal fx. Proximal fractures are at risk of nonunion/AVN
Lunate: moon shape. Four articulations: 1. radius (lunate facet), 2. scaphoid, 3. triquetrum, 4. capitate	4th	4yr	14-16yr	• Dislocations: rare but often missed • Will rotate (carpal instability) if ligamentous attachments to adjacent bones are disrupted
Triquetrum: pyramid shape. Lies under the pisiform and ulnar styloid	3rd	3yr	14-16yr	• 3rd most common carpal fracture • Articulates with TFCC
Pisiform: large sesamoid bone. In FCU tendon, anterolateral to triquetrum	8th	9-10yr	14-16yr	• Multiple attachments: FCU, transverse carpal ligament (TCL), abductor digiti minimi, multiple ligaments
DISTAL ROW				
Trapezium: saddle shape	6th	5-6yr	14-16yr	• Has groove for FCR tendon
Trapezoid: trapezoidal/wedge shape	7th	6-7yr	14-16yr	• Articulates with second metacarpal
Capitate: largest carpal bone, 1st carpal bone to ossify	1st	1yr	14-16yr	• Keystone to carpal arch, floor of CT • Retrograde blood supply
Hamate: has volar-oriented hook that is distal and radial to pisiform	2nd	2yr	14-16yr	• Hook can fx, ulnar a. can be injured • TCL attaches border of Guyon's canal

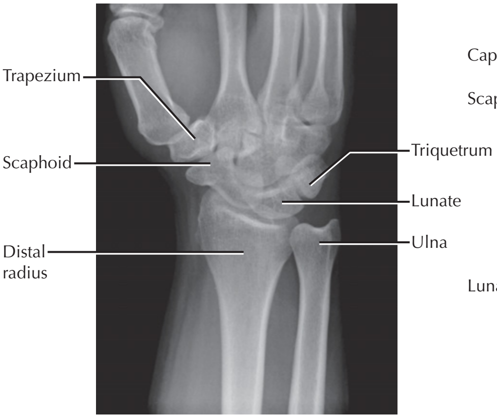
- Ossification: each from a single center in a counter-clockwise direction (anatomic position) starting with the capitate.
- Each bone has multiple (4-7) tight articulations with adjacent bones.
- Proximal row is considered the "intercalated segment" between the distal radius/TFCC and distal carpal row.
- Scaphoid-lunate angle (measured on lateral x-ray): avg. 47° (range 30-60°; <30=VISI, >60=DISI).


Capitate
Scaphoid
Scapho-lunate interval
Distal radius
Hook of hamate
Triquetrum
Pisiform
Lunate
Ulnar styloid
Ulna

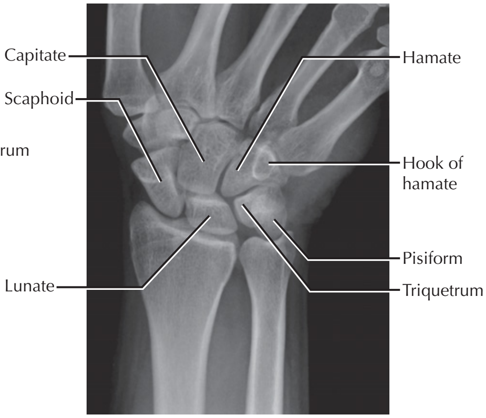
Wrist x-ray, AP


Distal pole of scaphoid
Pisiform
Radius
Capitate
Lunate
Ulna

Wrist x-ray, lateral


Trapezium
Scaphoid
Distal radius
Triquetrum
Lunate
Ulna

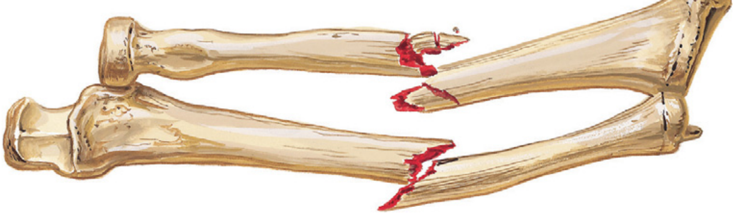
Wrist x-ray, oblique


Capitate
Scaphoid
Lunate
Hamate
Hook of hamate
Pisiform
Triquetrum

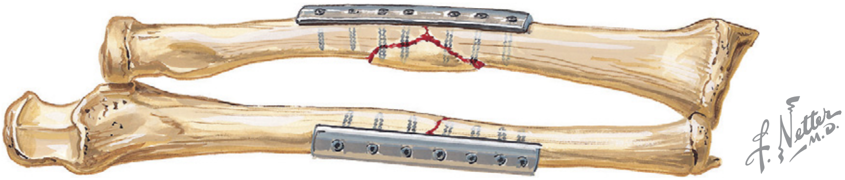
Wrist x-ray, ulnar deviation

RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
AP (anteroposterior)	Palm down on plate, beam perpendicular to plate	Carpal bones, radiocarpal joint	Distal radius, ulnar, carpal fractures or dislocation
Lateral	Ulnar border of wrist & hand on plate	Alignment of bones, joints	Same as above, carpal (lunate) instability
Oblique	Lateral with 40° rotation	Alignment & position of bones	Same as above
AP-ulnar deviation	AP, deviate wrist ulnarly	Isolates scaphoid	Scaphoid fractures
Carpal tunnel view	Maximal wrist extension, beam at 15°	Hamate, pisiform, trapezium	Fractures (esp. hook of the hamate)
OTHER STUDIES			
CT	Axial, coronal, & sagittal	Articular congruity, bone healing, bone alignment	Fractures (scaphoid, hook of hamate), nonunions
MRI	Sequence protocols vary	Soft tissues (ligaments, tendons, cartilage), bones	Occult fractures (e.g., scaphoid), tears (e.g., TFCC, S-L ligament)
Bone scan		All bones evaluated	Infection, stress fxs, tumors

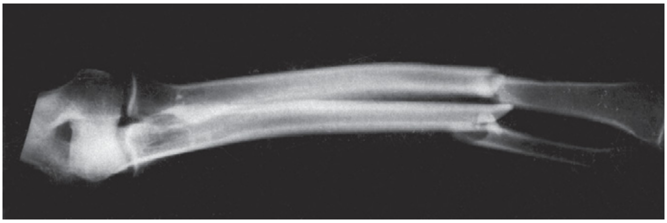
Fracture of Both Forearm Bones



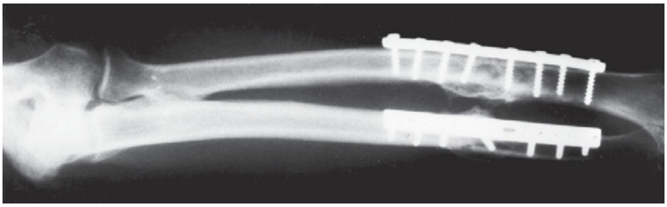
Fracture of both radius and ulna with angulation, shortening, and comminution of radius



Open reduction and fixation with compression plates and screws through both cortices. Good alignment, with restoration of radial bow and interosseous space.



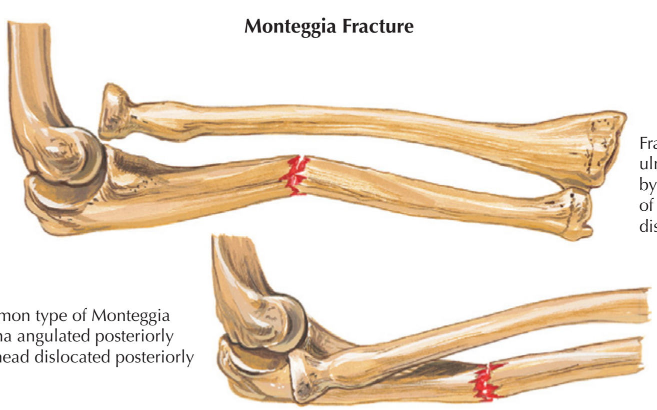
Preoperative radiograph. Fractures of shafts of both forearm bones



Postoperative radiograph. Compression plates applied and fragments in good alignment

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
RADIUS AND ULNA FRACTURES			
Both-Bone Fracture			
• Mech: fall or high energy • Both bones usually fracture as energy passes thru both bones • Fractures can be at different levels	**Hx:** Trauma, pain and swelling, +/– deformity **PE:** Swelling, tenderness, +/– clinical deformity **XR:** AP & lateral forearm	Descriptive: • Proximal, middle, distal ⅓ • Displaced/angulated • Comminuted • Open or closed	• Peds (<10-12y.o.): closed reduction and casting • Adults: ORIF (plates & screws) through separate incisions
COMPLICATIONS: Malunion (loss of radial bow leads to decreased pronosupination), decreased range of motion			
Single-Bone Fracture			
• Mechanism: direct blow; aka "nightstick fracture" • Ulna most common	**Hx:** Direct blow to forearm **PE:** Swelling, tenderness **XR:** AP & lateral forearm	Descriptive: • Displaced, shortened, angulated, comminuted	• Nondisplaced: cast • Displaced: ORIF
COMPLICATIONS: Nonunion, malunion			

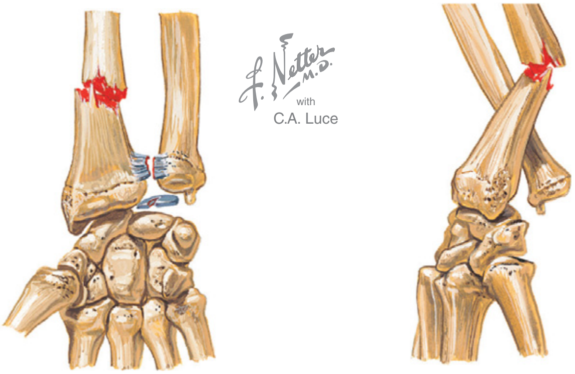
Monteggia Fracture



Fractures of proximal ulna often characterized by anterior angulation of ulna and anterior dislocation of radial head

In less common type of Monteggia fracture, ulna angulated posteriorly and radial head dislocated posteriorly

Galeazzi Fracture

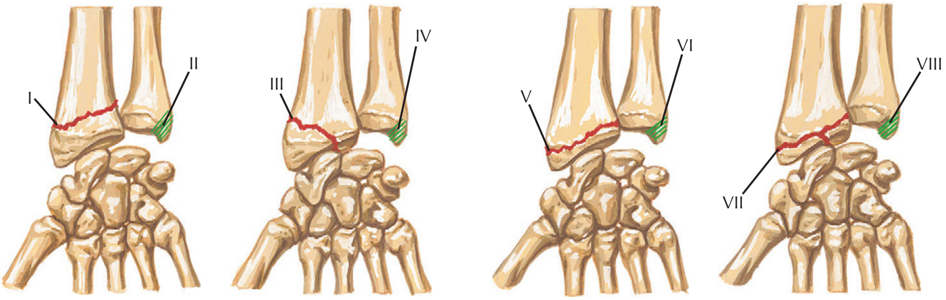


Anteroposterior view of fracture of radius plus dislocation of distal radioulnar joint

Dislocation of distal radioulnar joint better demonstrated in lateral view

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
MONTEGGIA FRACTURE			
• Proximal ulna fracture, shortening forces result in radial head dislocation • Mechanism: direct blow or fall on outstretched hand	**Hx:** Fall, pain and swelling **PE:** Tenderness, deformity. Check compartments and do neurovascular exam **XR:** AP/lateral: forearm; also, wrist and elbow	Bado (based on RH location): • I: Anterior (common) • II: Posterior • III: Lateral • IV: Anterior with associated both-bone fracture	• Ulna: ORIF (plate/screws) • Radial head: closed reduction (open if irreducible or unstable) • Peds: closed reduction and cast
COMPLICATIONS: Radial nerve/PIN injury (most resolve), decreased ROM, compartment syndrome, nonunion			
GALEAZZI FRACTURE			
• Mechanism: fall on outstretched hand • Distal ⅓ radial shaft fracture, shortening forces result in distal radioulnar dislocation	**Hx:** Fall, pain and swelling **PE:** Tenderness, deformity. Check compartments and do neurovascular exam **XR:** AP/lateral forearm: ulna usually dorsal. Also, wrist and elbow series	By mechanism: • Pronation: Galeazzi • Supination: Reverse Galeazzi (ulna shaft fx with DRUJ dislocation)	• Radius: ORIF • DRUJ: closed reduction, +/− percutaneous pins in supination if unstable (open if unstable) • Cast for 4-6wk • Peds: reduce & cast
COMPLICATIONS: Nerve injury, decreased ROM, nonunion, DRUJ arthrosis			

Frykman Classification of Fractures of Distal Radius



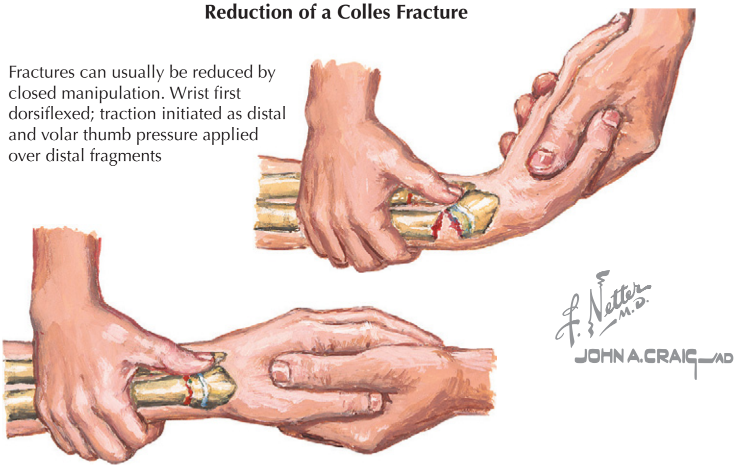
Extraarticular radius: I
Ulnar styloid: II

Radiocarpal intraarticular: III
Ulnar styloid: IV

Intraarticular distal radioulnar: V
Ulnar styloid: VI

Intraarticular radiocarpal and distal radioulnar: VII
Ulnar styloid: VIII

Reduction of a Colles Fracture

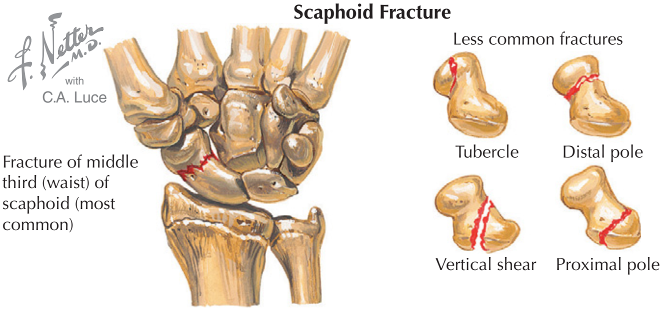


Fractures can usually be reduced by closed manipulation. Wrist first dorsiflexed; traction initiated as distal and volar thumb pressure applied over distal fragments

With pressure and traction maintained, wrist gently straightened

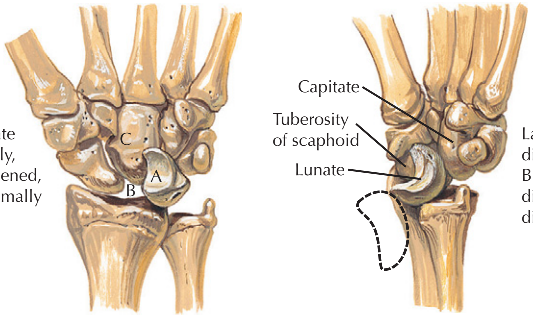
DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
DISTAL RADIUS FRACTURE			
• Mechanism: fall on outstretched hand • Very common (Colles #1) • Cancellous bone susceptible to fx (incl. osteoporotic fx) • Colles (#1): dorsal displacement (apex volar angulation) • Smith fx: volar displacement • Barton fx: articular rim fx • Radial styloid ("chauffeur fx")	**Hx:** Trauma (usually fall), pain and swelling **PE:** Swelling, tenderness, +/− deformity. Do thorough neurovascular exam. **XR:** Wrist series (3 views) Normal measurements ◦ 11° volar tilt ◦ 11-12mm radial height ◦ 23° radial inclination **CT:** For intraarticular fxs	Frykman (for Colles): • Type I, II: extraarticular • Type III, IV: RC joint • Type V, VI: RC joint • Type VII, VIII: both radioulnar & radiocarpal (RC) joints involved • Even # fxs have associated ulnar styloid fx Other fxs, descriptive: displaced, angulated	• Nondisplaced: cast • Displaced: ◦ Stable: closed reduction, well-molded cast, 4-6wk ◦ Unstable: closed reduction, percutaneous pinning +/− ext. fix. or ORIF • Intraarticular: ORIF (e.g., volar plate) • Elderly: cast, early ROM
COMPLICATIONS: Malunion, posttraumatic osteoarthritis, stiffness/loss of range of motion			

Scaphoid Fracture



Fracture of middle third (waist) of scaphoid (most common)

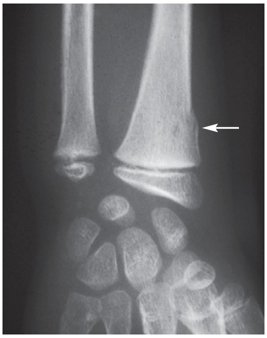
Perilunate Dislocation

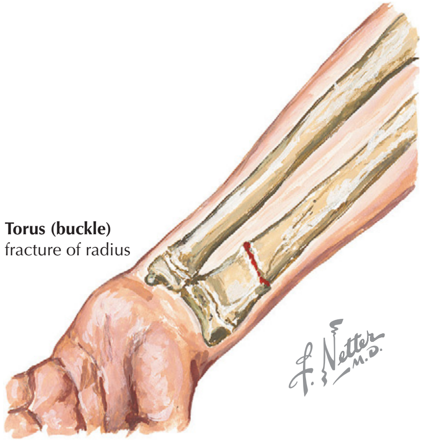


Palmar view shows (A) lunate rotated and displaced volarly, (B) scapholunate space widened, (C) capitate displaced proximally and dorsally

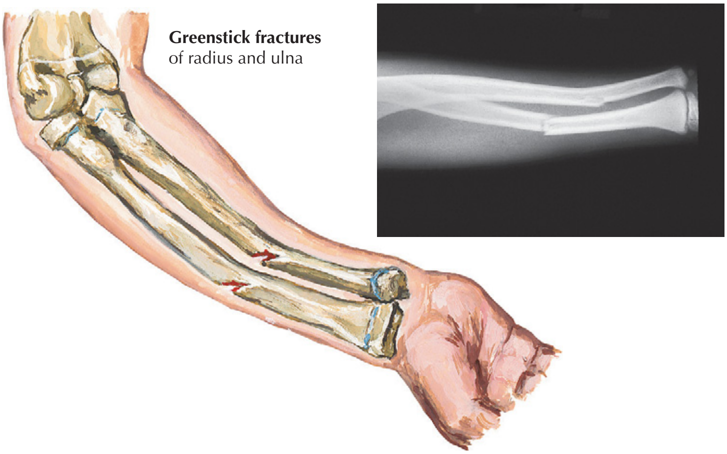
Lateral view shows lunate displaced volarly and rotated. Broken line indicates further dislocation to volar aspect of distal radius

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
SCAPHOID FRACTURE			
• Mechanism: fall on outstretched hand • Most common carpal fx • Retrograde blood suppy to proximal pole is injured in waist fxs, can lead to nonunion or AVN • Distal pole usually heals • High index of suspicion will decrease missed fxs	**Hx:** Trauma (usually fall), pain and swelling **PE:** "Snuffbox" tenderness, decreased ROM **XR:** Wrist & ulnar deviation views **CT:** For most fxs; shows displacement/pattern **MR:** Occult fx, AVN	Location: • Proximal pole • Middle/"waist" (#1) • Distal pole Position: • Displaced • Angulated/shortened	• Nondisplaced: 1. Casting (LAC & SAC) average 10-12wk; 2. Percutaneous screw • Displaced: ORIF +/− bone graft • Nonunion: ORIF with tricortical bone graft or vascularized bone graft
COMPLICATIONS: Nonunion, wrist arthrosis (SLAC wrist from chronic nonunion), osteonecrosis (esp. proximal pole)			
PERILUNATE INSTABILITY/DISLOCATION			
• Mech: fall; axial compression & hyperextension • Instability progresses through 4 stages (Mayfield) as various ligaments are disrupted • Dislocation (stage 4) occurs through weak spot (space of Poirier) • Transscaphoid dislocation is #1 injury pattern	**Hx:** Trauma/fall, pain **PE:** Characteristic volar "fullness", decr. ROM **XR:** S-L gap >3mm S-L angle: >60° or <30° **CT:** Evaluate carpal fxs **MR:** Shows ligament injury in subtle early stages	Instability (Mayfield (4)) • I: Scapholunate disruption • II: Lunocapitate disruption • III: Lunotriquetral disruption • IV: Lunate (peri) dislocation Dislocation (Stage 4 instability) • Lesser arc: ligaments only • Greater arc: assoc. carpal fx	• Instability: closed vs open reduction, percutaneous pinning & primary ligament repair • Dislocation: open reduction of lunate, percutaneous pinning +/− ORIF of carpal fx • Late/wrist arthrosis: proximal row carpectomy or STT fusion
COMPLICATIONS: Wrist arthrosis (e.g., SLAC from instability), nonunion of fracture, chronic pain and/or instability			



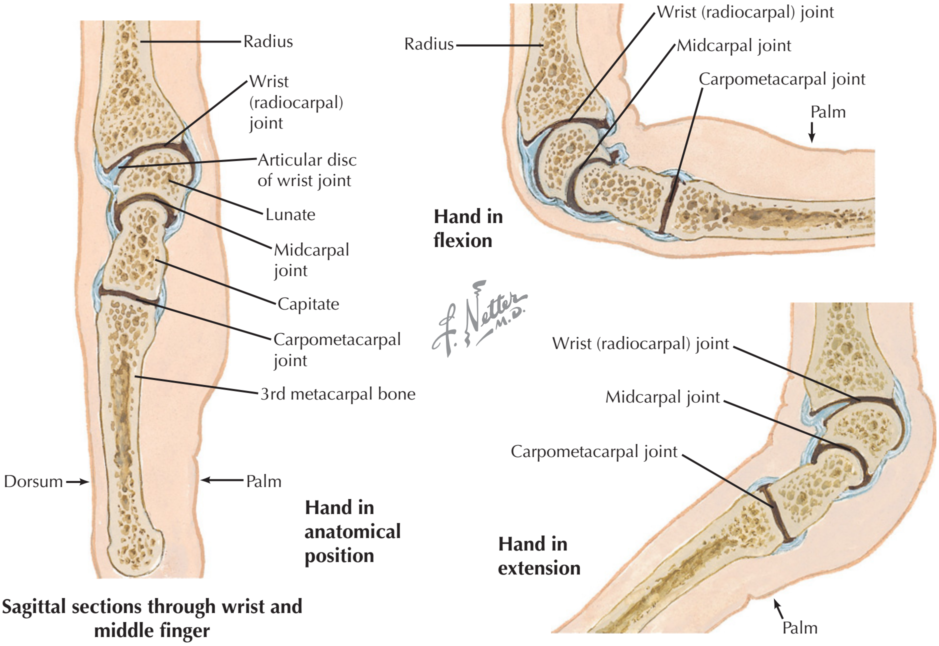


Torus (buckle) fracture of radius



Greenstick fractures of radius and ulna

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
INCOMPLETE FRACTURE: TORUS AND GREENSTICK FRACTURE			
• Common in children (usually 3-12y.o.) • Mechanism: fall on outstretched hand most common • Distal radius most common • Increased elasticity of pediatric bone allows for plastic deformity and/or unicortical fx	**Hx:** Trauma, pain, inability/ unwilling to use hand/ extremity **PE:** +/– deformity. Point tenderness & swelling **XR:** AP and lateral. Torus: cortical "buckle." Greenstick: unicortical fracture	• Torus (buckle): concave cortex compresses (buckles), convex/ tension side: intact • Greenstick: concave, cortex intact or buckled, convex/ tension side fracture or plastic deformity	• Torus: reduction rarely needed, cast 2-4wk • Greenstick: nondisplaced—SAC 2-4wk. Reduce if >10° of angulation—well-molded LAC 3-4wk
COMPLICATIONS: Deformity, malunion, neurovascular injury (rare)			


Radius
Wrist (radiocarpal) joint
Articular disc of wrist joint
Lunate
Midcarpal joint
Capitate
Carpometacarpal joint
3rd metacarpal bone
Dorsum
Palm
Hand in anatomical position
Radius
Wrist (radiocarpal) joint
Midcarpal joint
Carpometacarpal joint
Palm
Hand in flexion
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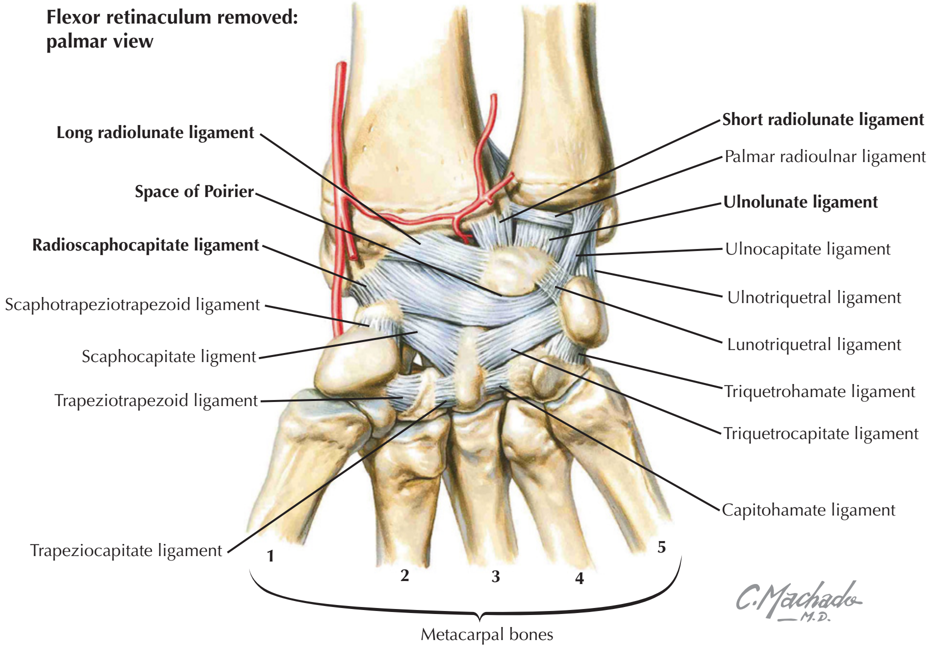
Wrist (radiocarpal) joint
Midcarpal joint
Carpometacarpal joint
Hand in extension
Palm

Sagittal sections through wrist and middle finger

WRIST

GENERAL

- The wrist is a complex joint comprising 3 main articulations: 1. Radiocarpal (distal radius/TFCC to proximal row), 2. Distal radioulnar joint (DRUJ), 3. Midcarpal (between carpal rows)
- Other articulations: pisotriquetral and multiple intercarpal (between 2 adjacent bones in the same row)
- Proximal row has no muscular attachments, considered the “intercalated segment,” & responds to transmitted forces. Distal row bones are tightly connected and act as a single unit in a normal wrist.
- Range of motion:
  - Flexion 65-80° (40% from radiocarpal, 60% midcarpal); extension 55-75° (65% radiocarpal, 35% midcarpal)
  - Radial deviation: 15-25°; ulnar deviation: 30-45° (55% midcarpal, 45% radiocarpal)
- Types of ligaments
  - **Extrinsic:** connect the distal forearm (radius & ulna) to the carpus
  - **Intrinsic:** connect carpal bones to each other (i.e., origin and insertion of ligament both within the carpus)
    - Interosseous: ligaments connecting carpal bones within the same row (proximal or distal)
    - Midcarpal/Intercarpal: ligaments connecting carpal bones between the proximal and distal rows.
- Palmar (volar) ligaments are stronger and more developed; most are intracapsular.

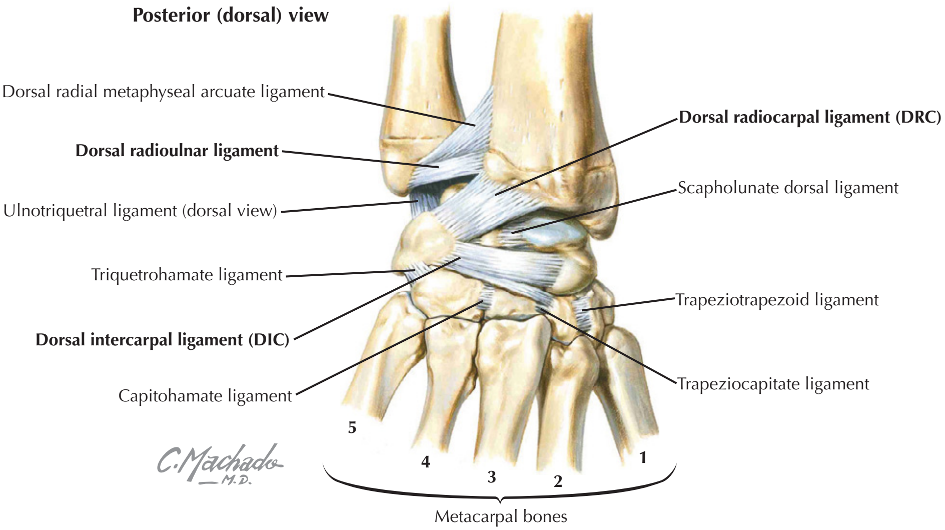


Flexor retinaculum removed: palmar view

Long radiolunate ligament
Space of Poirier
Radioscaphocapitate ligament
Scaphotrapeziotrapezoid ligament
Scaphocapitate ligment
Trapeziotrapezoid ligament
Trapeziocapitate ligament
Short radiolunate ligament
Palmar radioulnar ligament
Ulnolunate ligament
Ulnocapitate ligament
Ulnotriquetral ligament
Lunotriquetral ligament
Triquetrohamate ligament
Triquetrocapitate ligament
Capitohamate ligament
1
2
3
4
5
Metacarpal bones
C.Machado M.D.

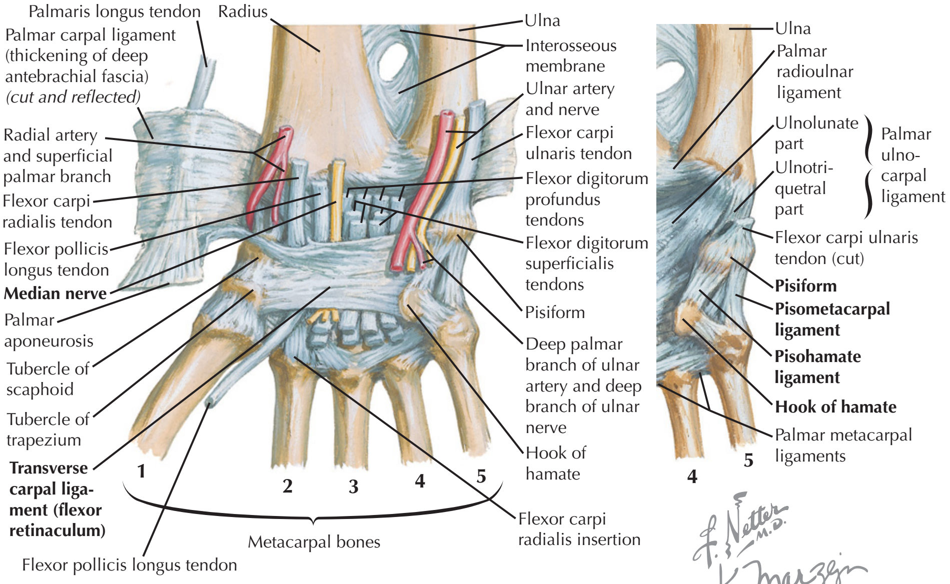
LIGAMENTS	ATTACHMENTS	FUNCTION/COMMENT
RADIOCARPAL JOINT		
Extrinsic—Palmar		
Superficial		
Radioscaphocapitate ◦ Radioscaphoid (RS) ◦ Radiocapitate (RC)	Radius to carpus Radial styloid to scaphoid Radius to capitate body	Blends with UC to form distal border of space of Poirier Aka "radial collateral" lig. Stabilizes proximal pole Forms a fulcrum around which the scaphoid rotates
Long radiolunate (lRL)	Volar radius to lunate	Blends with palmar LT interosseous ligament
Ulnocapitate (UC)	Ulna/TFC to capitate	Blends with RSC laterally. Distal border of space of Poirier
Deep		
Short radiolunate (sRL)	Distal radius to lunate	**Stout & vertical. Prevents dx in hyperextension**
Ulnolunate (UL)	TFC to lunate	UL & UT blend with UC to help stabilize the DRUJ
Ulnotriquetral (UT)	TFC to triquetrum	UL & UT considered by some to be part of the TFCC
Radioscapholunate	Radius to SL joint	"Ligament of Testut," a neurovascular bundle to SL jt.
Extrinsic—Dorsal		
Dorsal radiocarpal (DRC) ◦ Superficial bundle ◦ Deep bundle	Radius to lunate/triquetrum Radius to triquetrum Radius to LT joint	Aka radiolunotriquetral (RLT); main dorsal stabilizer The two bundles are typically indistinguishable Fibers attach to lunate and/or lunotriquetral ligament

- Space of Poirier: weak spot volarly where perilunate dislocations occur (between the proximal edge of RSC & UC ligaments distally and distal edge of lRL ligament proximally).
- No true ulnar collateral ligament exists in the wrist. The ECU & sheath provide some ulnar collateral support.
- Deep volar extrinsic ligaments can be seen easily during wrist arthroscopy; the superficial ones are difficult to visualize.
- The UC, UL, and UT form the ulnocarpal ligamentous complex.

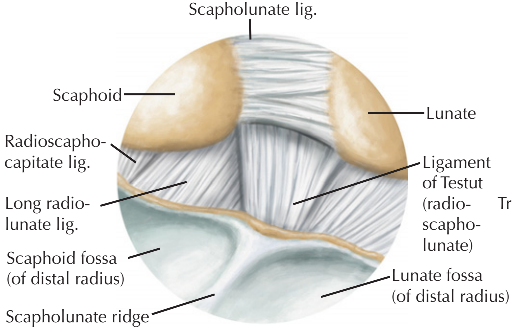

Posterior (dorsal) view
Dorsal radial metaphyseal arcuate ligament
Dorsal radioulnar ligament
Ulnotriquetral ligament (dorsal view)
Triquetrohamate ligament
Dorsal intercarpal ligament (DIC)
Capitohamate ligament
Dorsal radiocarpal ligament (DRC)
Scapholunate dorsal ligament
Trapeziotrapezoid ligament
Trapeziocapitate ligament
5
4
3
2
1
Metacarpal bones
C. Machado M.D.

LIGAMENTS	ATTACHMENTS	FUNCTION / COMMENT
INTRINSIC LIGAMENTS		
Midcarpal Joint		
Palmar		
Triquetrohamocapitate (THC) ◦ Triquetrohamate (TH) ◦ Triquetrocapitate (TC)	Triquetrum to: Hamate Capitate	Medial/ulnar portion of arcuate ligament Short, stout ligament Often confluent with the ulnocapitate part (UC) ligament
Scaphocapitate (SC)	Scaphoid to capitate	Stabilizes distal scaphoid. Radial part of arcuate lig.
Dorsal		
Dorsal intercarpal (DIC)	Triq. to tpzm./tpzd.	A primary dorsal support
Scaphotrapeziotrapezoid (STT)	Scaph. to tpzm./tpzd.	Lateral (radial) and scaphotrapezial joint support
Interosseous Joints		
PROXIMAL ROW: 2 joints. Ligaments are “C” shaped with dorsal and palmar limbs and a membranous portion between. The membrane prevents communication b/w the radiocarpal and midcarpal joints. It does not add stability. 1. Scapholunate (SL) joint: Scaphoid gives a flexion force to the lunate. Arch of motion during ROM: scaphoid>lunate. 2. Lunotriquetral (LT) joint: Triquetrum provides an extension force to the lunate, which is resisted by the LT.		
Scapholunate (SL or SLIL)	Scaphoid to lunate	Dorsal fibers strongest. Disruption: instability, (DISI) Palmar fibers are looser & allow scaphoid rotation
Lunotriquetral (LT)	Lunate to triquetrum	Palmar fibers strongest. Disruption (with DRC ligament injury) leads to carpal instability (VISI)
DISTAL ROW: 3 joints as below. Strong interosseous ligaments keep distal row moving as a single unit.		
Trapeziotrapezium Capitotrapezoid Capitohamate	Trapezoid to trapezium Capitate to trapezium Capitate to hamate	Each ligament has 3 parts (palmar, dorsal, deep/interosseous). Distal row ligaments are stronger than in proximal row. CH lig. is strongest distal row ligament.
Pisotriquetral Articulation		
Pisohamate	Pisiform to hamate	Inserts on hook of hamate; part of Guyon’s canal
Pisometacarpal	Pisiform to 5th MC base	Assists in FCU flexion

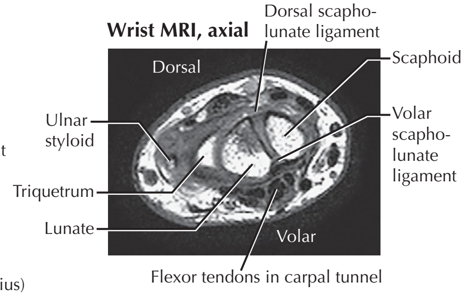
Carpal tunnel: palmar view


Palmaris longus tendon
Radius
Palmar carpal ligament (thickening of deep antebrachial fascia) *(cut and reflected)*
Radial artery and superficial palmar branch
Flexor carpi radialis tendon
Flexor pollicis longus tendon
Median nerve
Palmar aponeurosis
Tubercle of scaphoid
Tubercle of trapezium
Transverse carpal ligament (flexor retinaculum)
Flexor pollicis longus tendon
1
2
3
4
5
Metacarpal bones
Ulna
Interosseous membrane
Ulnar artery and nerve
Flexor carpi ulnaris tendon
Flexor digitorum profundus tendons
Flexor digitorum superficialis tendons
Pisiform
Deep palmar branch of ulnar artery and deep branch of ulnar nerve
Hook of hamate
Flexor carpi radialis insertion
Ulna
Palmar radioulnar ligament
Ulnolunate part
Ulnotriquetral part
Palmar ulnocarpal ligament
Flexor carpi ulnaris tendon (cut)
Pisiform
Pisometacarpal ligament
Pisohamate ligament
Hook of hamate
Palmar metacarpal ligaments
4
5

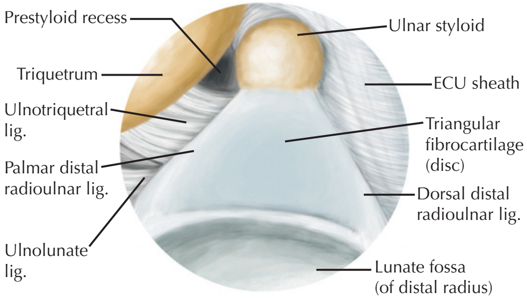
Radiocarpal joint


Scapholunate lig.
Scaphoid
Radioscaphocapitate lig.
Long radiolunate lig.
Scaphoid fossa (of distal radius)
Scapholunate ridge
Lunate
Ligament of Testut (radioscapholunate)
Lunate fossa (of distal radius)

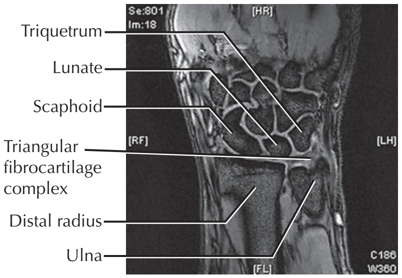
Wrist MRI, axial

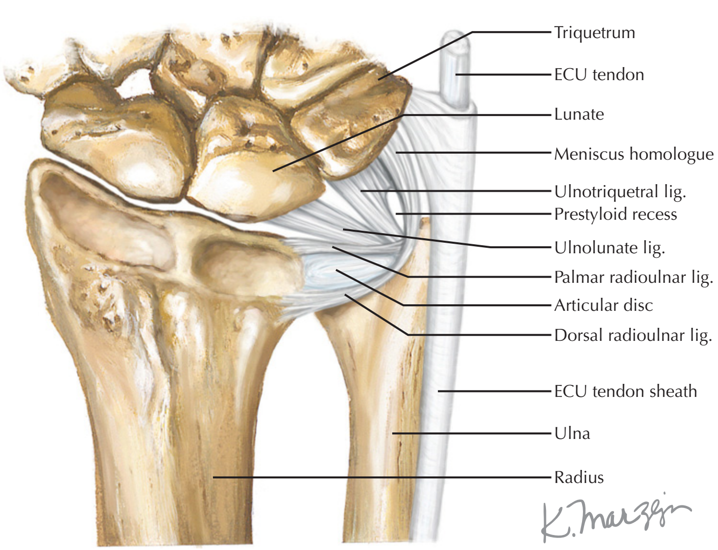

Dorsal scapholunate ligament
Dorsal
Scaphoid
Ulnar styloid
Volar scapholunate ligament
Triquetrum
Lunate
Volar
Flexor tendons in carpal tunnel

Triangular fibrocartilage complex


Prestyloid recess
Triquetrum
Ulnotriquetral lig.
Palmar distal radioulnar lig.
Ulnolunate lig.
Ulnar styloid
ECU sheath
Triangular fibrocartilage (disc)
Dorsal distal radioulnar lig.
Lunate fossa (of distal radius)

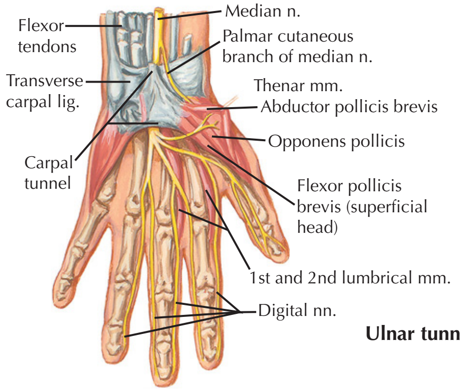
Wrist MRI, coronal

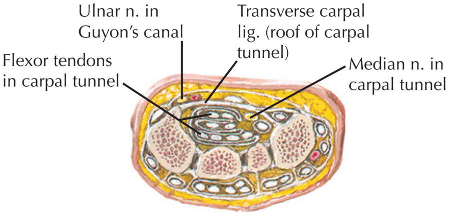

Se:801
Im:18
[HR]
[RF]
[LH]
[FL]
C186
W360
Triquetrum
Lunate
Scaphoid
Triangular fibrocartilage complex
Distal radius
Ulna



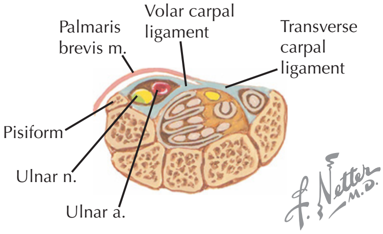
LIGAMENTS	ATTACHMENTS	FUNCTION / COMMENT
DISTAL RADIOULNAR JOINT		
• This joint (DRUJ) is stabilized by a combination of structures that form the triangular fibrocartilage complex (TFCC). • Primary motion is pronation (60-80°) & supination (60-85°); the radius rotates around the stationary ulna. • 20% of an axial load is transmitted to ulna in an ulnar neutral wrist. The ulna takes more load when it is ulna positive.		
Triangular Fibrocartilage Complex		
• TFCC is interposed between the distal ulna and the ulnar proximal carpal row (triquetrum). It originates at the articular margin of the sigmoid notch (radius) and inserts at the base of the ulnar styloid. • Vascular supply to TFCC (from ulnar artery & anterior interosseous artery) penetrate the peripheral 10%-25%.		
Triangular fibrocartilage	Radius to ulna fovea (deep fibers) & styloid (superficial fibers)	TFC has 3 portions: central disc and 2 peripheral (radioulnar) ligaments
◦ Central (articular) disc	Blends w/ radial articular cartilage	Resists compression and tension; avascular and aneural
◦ Dorsal radioulnar	Dorsal radius to ulnar fovea (ligamentum subcruentum)	Blends with TFC, tight in pronation, loose in supination
◦ Palmar radioulnar	Volar radius to ulnar fovea (ligamentum subcruentum)	Blends with TFC, tight in supination, loose in pronation
Meniscal homologue	Dorsal radius to volar triquetrum	Highly vascular synovial fold
ECU tendon sheath	Ulna styloid, triquetrum, hamate	Considered an "ulnar collateral ligament"
Other		
• UL, UT, and prestyloid recess are considered by some to be a part of the TFCC.		
Ulnolunate (UL) Ulnotriquetral (UT)	TFC to lunate TFC to triquetrum	UL & UT blend with ulnocapitate lig. to contribute to fxn of TFCC and stabilize the DRUJ.
Prestyloid recess	None	Between palmar radioulnar ligament & meniscus homologue
• Other structures contributing to DRUJ stability: ECU, pronator quadratus, interosseous membrane. • TFCC can be torn (degenerative or traumatic). Peripheral tears can be repaired, central tears need debridement.		

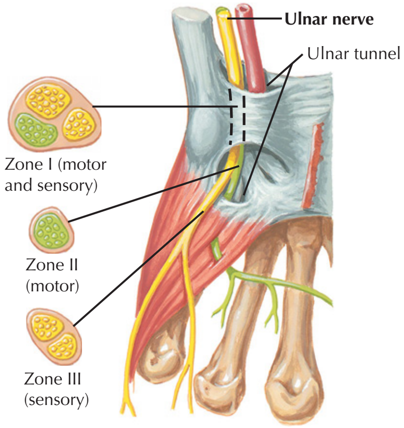
Carpal tunnel


Flexor tendons
Transverse carpal lig.
Carpal tunnel
Median n.
Palmar cutaneous branch of median n.
Thenar mm.
Abductor pollicis brevis
Opponens pollicis
Flexor pollicis brevis (superficial head)
1st and 2nd lumbrical mm.
Digital nn.


Ulnar n. in Guyon's canal
Transverse carpal lig. (roof of carpal tunnel)
Flexor tendons in carpal tunnel
Median n. in carpal tunnel

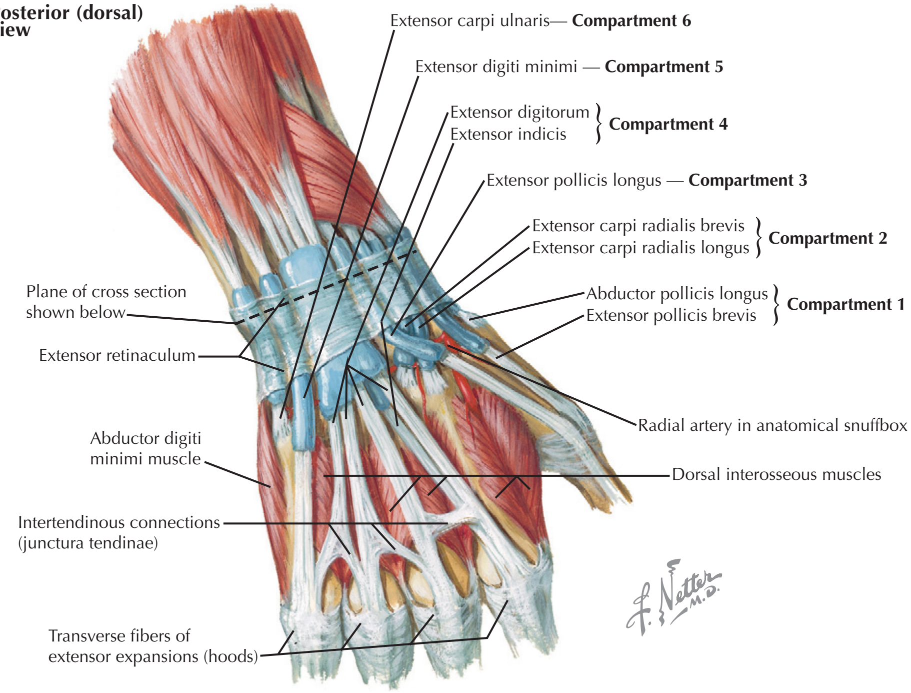
Ulnar tunnel


Palmaris brevis m.
Volar carpal ligament
Transverse carpal ligament
Pisiform
Ulnar n.
Ulnar a.

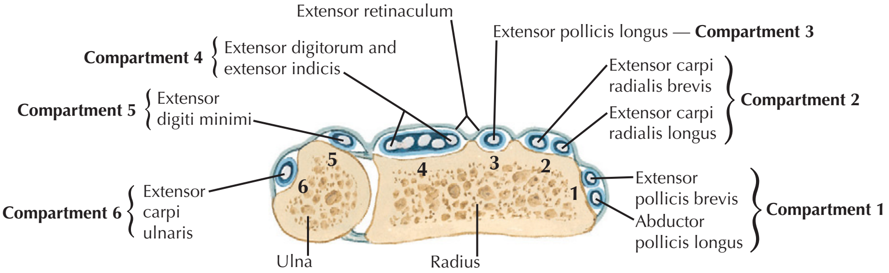

Ulnar nerve
Ulnar tunnel
Zone I (motor and sensory)
Zone II (motor)
Zone III (sensory)

STRUCTURE	COMPONENTS	COMMENTS
CARPAL TUNNEL		
Transverse carpal ligament (TCL, flexor retinaculum)	Attachments: Medial: pisiform and hamate Lateral: scaphoid and trapezium	• Roof of carpal tunnel, can compress median nerve. TCL is incised in a carpal tunnel release. • Tunnel is narrowest at hook of hamate
Borders	Roof: transverse carpal ligament Floor: central carpal bones Medial wall: pisiform and hamate Lateral wall: trapezium and scaphoid	• See above • Especially capitate and trapezoid • Hook of hamate gives medial wall • Trapezium is primary wall structure
Contents	Tendons: FDS (4), FDP (4), FPL Nerve: median	• 9 tendons within the carpal tunnel • Compressed in carpal tunnel syndrome
• Thenar motor branch of median nerve can exit under, through, or distal to the transverse carpal ligament. • A persistent median artery or aberrant muscle can occur in the tunnel and may cause carpal tunnel syndrome.		
ULNAR TUNNEL / GUYON'S CANAL		
Borders	Floor: transverse carpal ligament Roof: volar carpal ligament Medial wall: pisiform Lateral wall: hook of hamate	• Can be released simultaneously with CTR • Continuous with deep antebrachial fascia • Neurovascular bundle is under pisohamate ligament • Fracture can cause nerve compression.
Contents	Ulnar nerve Ulnar artery	• Divides in canal to deep & superficial branches • Terminates as superficial arch around hamate
• Fractures (malunion) or masses (e.g., ganglion cysts #1) can compress the ulnar nerve or artery within the canal.		

Posterior (dorsal) view


Extensor carpi ulnaris— **Compartment 6**
Extensor digiti minimi — **Compartment 5**
Extensor digitorum
Extensor indicis
Compartment 4
Extensor pollicis longus — **Compartment 3**
Extensor carpi radialis brevis
Extensor carpi radialis longus
Compartment 2
Abductor pollicis longus
Extensor pollicis brevis
Compartment 1
Plane of cross section shown below
Extensor retinaculum
Radial artery in anatomical snuffbox
Abductor digiti minimi muscle
Dorsal interosseous muscles
Intertendinous connections (junctura tendinae)
Transverse fibers of extensor expansions (hoods)

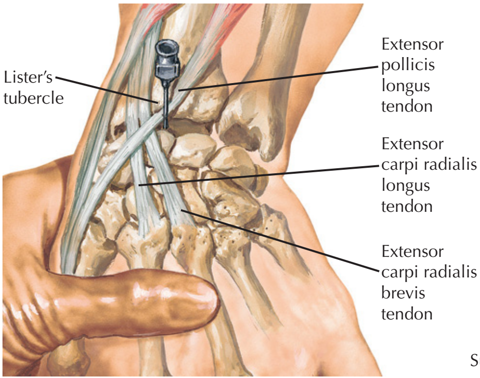
Cross section of most distal portion of forearm


Extensor retinaculum
Compartment 4
Extensor digitorum and extensor indicis
Extensor pollicis longus — **Compartment 3**
Compartment 5
Extensor digiti minimi
Extensor carpi radialis brevis
Extensor carpi radialis longus
Compartment 2
Compartment 6
Extensor carpi ulnaris
5
6
4
3
2
1
Extensor pollicis brevis
Abductor pollicis longus
Compartment 1
Ulna
Radius

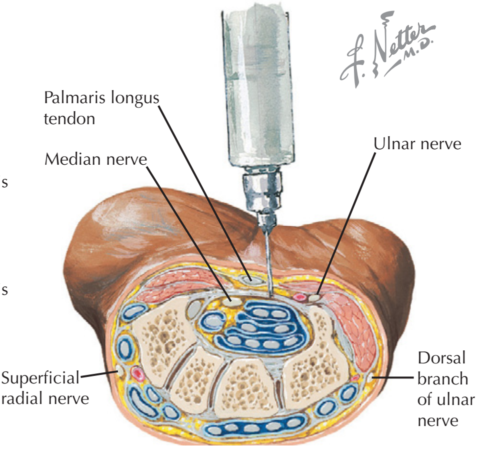
STRUCTURE	FUNCTION		COMMENTS
EXTENSOR COMPARTMENTS			
Extensor retinaculum	Covers the wrist dorsally		Forms six fibro-osseous compartments through which the extensor tendons pass
	Number	**Tendon**	**Clinical Condition**
Dorsal compartments	I	EPB, APL	de Quervain's tenosynovitis can develop here
	II	ECRL, ECRB	Tendinitis can occur here
	III	EPL	Travels around Lister's tubercle, can rupture
	IV	EDC, EIP	This compartment split in dorsal wrist approach
	V	EDQ (EDM)	Rupture (Jackson-Vaughn syndrome) in RA
	VI	ECU	Tendon can snap over ulnar styloid causing pain

- EIP and EDQ tendons are ulnar to EDC tendons to the index and small fingers, respectively.
- 1st compartment may have multiple slips that all need to be released in de Quervain's disease for a full release.

Wrist Injection


Lister's tubercle
Extensor pollicis longus tendon
Extensor carpi radialis longus tendon
Extensor carpi radialis brevis tendon

Carpal Tunnel Injection



STEPS

WRIST ASPIRATION/INJECTION

1. Ask patient about allergies
2. Palpate radiocarpal joint dorsally, find Lister's tubercle and the space ulnar to it
3. Prep skin over dorsal wrist (iodine/antiseptic soap)
4. Anesthetize skin locally (quarter size spot)
5. Aspiration: insert 20-gauge needle into space ulnar to Lister's tubercle/EPL/ECRB and radial to EDC, aspirate. Injection: insert 22-gauge needle into same space, aspirate to ensure not in vessel, then inject 1-2ml of local or local/steroid preparation into RC joint.
6. Dress injection site
7. If suspicious for infection, send fluid for Gram stain and culture

CARPAL TUNNEL INJECTION/MEDIAN NERVE BLOCK

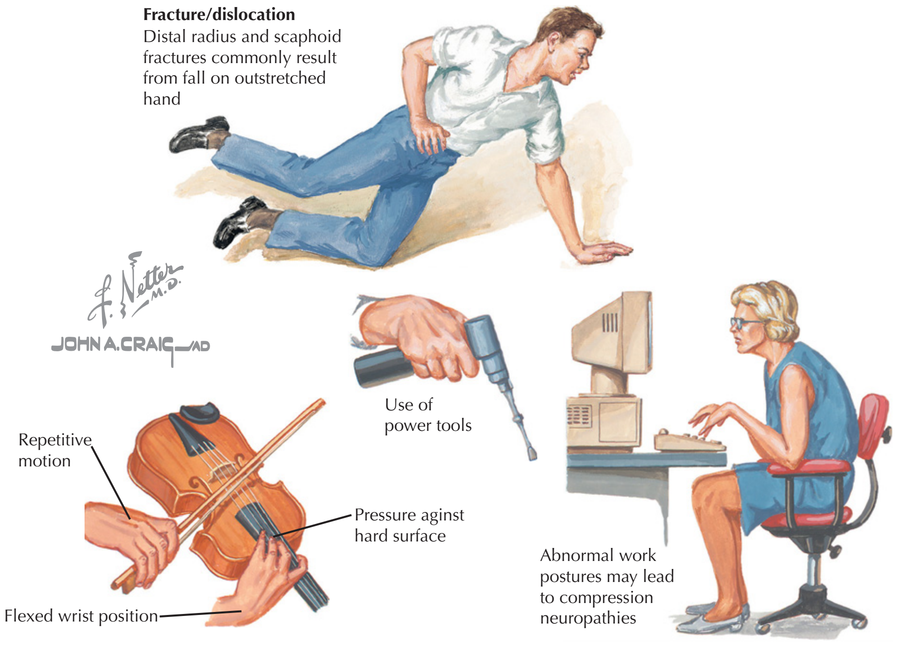
1. Ask patient about allergies
2. Ask patient to pinch thumb and small finger tips; palmaris longus (PL) tendon will protrude (10% -20% do not have one). Median nerve is beneath PL, just ulnar to FCR within the carpal tunnel.
3. Prep skin over volar wrist (iodine/antiseptic soap)
4. Anesthetize skin locally (quarter size spot)
5. Insert 22-gauge or smaller needle into wrist ulnar to PL at flexion crease at 45° angle. Aspirate to ensure needle is not in a vessel. Inject 1-2ml of local or local/steroid preparation.
6. Dress injection site

WRIST BLOCK

Four separate nerves are blocked. Based on the necessary anesthesia, a complete or partial block can be performed:

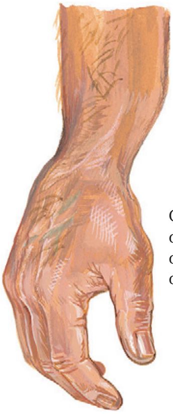
1. Ask patient about allergies
2. Prep skin over each landmark (iodine/antiseptic soap)
3. **Ulnar nerve:** palpate the FCU tendon just proximal to volar wrist crease. Insert needle under the FCU tendon. Aspirate to ensure needle is not in ulnar artery (nerve is ulnar to the artery). Inject 3-4ml of local anesthetic into the space dorsal to the FCU tendon.
4. **Dorsal cutaneous branch** of ulnar nerve: palpate the distal ulna/styloid. Inject a large subcutaneous wheal on the dorsal and ulnar aspect of the wrist, just proximal to the ulnar styloid.
5. **Superficial radial nerve:** block at radial styloid with a large subcutaneous wheal on the dorsoradial aspect of the wrist.
6. **Median nerve:** block in carpal tunnel as described above
7. **Palmar cutaneous branch** of median nerve: raise a wheal over the central volar wrist.

- Median and superficial radial nerve blocks are effective for thumb, index finger, and most middle finger injuries.
- Ulnar and dorsal cutaneous branch blocks are used for small finger injuries. Most ring finger injuries require complete wrist block.


Fracture/dislocation
Distal radius and scaphoid fractures commonly result from fall on outstretched hand
F. Netter M.D.
JOHN A.CRAIG MD
Use of power tools
Repetitive motion
Pressure aginst hard surface
Flexed wrist position
Abnormal work postures may lead to compression neuropathies

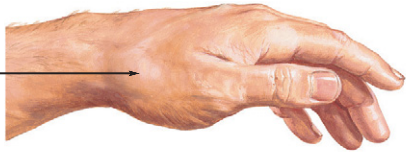
QUESTION	ANSWER	CLINICAL APPLICATION
1. Age	Young Middle aged, elderly	Trauma: fractures and dislocations, ganglions Arthritis, nerve entrapments, overuse
2. Pain		
a. Onset	Acute Chronic	Trauma Arthritis
b. Location	Dorsal Volar Radial Ulnar	Kienböck's disease, ganglion Carpal tunnel syndrome (CTS), ganglion (esp. radiovolar) Scaphoid fracture, de Quervain's tenosynovitis, arthritis Triangular fibrocartilage complex (TFCC) tear, tendinitis (e.g., ECU)
3. Stiffness	With dorsal pain With volar pain (at night)	Kienböck's disease Carpal tunnel syndrome
4. Swelling	Joint: after trauma Joint: no trauma Along tendons	Fracture or sprain Arthritides, infection, gout Flexor or extensor tendinitis (calcific), de Quervain's disease
5. Instability	Popping, snapping	Carpal instability (e.g., scapholunate dislocation)
6. Mass	Along wrist joint	Ganglion
7. Trauma	Fall on hand	Fractures: distal radius, scaphoid; dislocation: lunate; TFCC tear
8. Activity	Repetitive motion (e.g., typing)	CTS, de Quervain's tenosynovitis
9. Neurologic symptoms	Numbness, tingling Weakness	Nerve entrapment (e.g., CTS), thoracic outlet syndrome, radiculopathy (cervical spine) Nerve entrapment (median, ulnar, radial)
10. History of arthritides	Multiple joints involved	Arthritides

Distal Radius Fracture



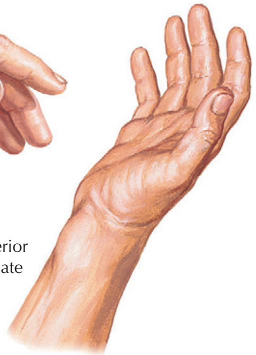
Clinical appearance of deformity due to severely displaced fracture of distal radius

Scaphoid Fracture



Clinical findings. Pain, tenderness, and swelling in anatomic snuffbox

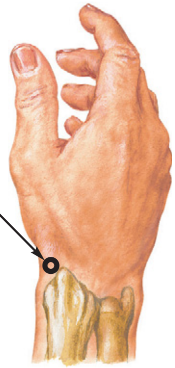
Carpal Dislocation



Typical deformity. Anterior bulge of dislocated lunate

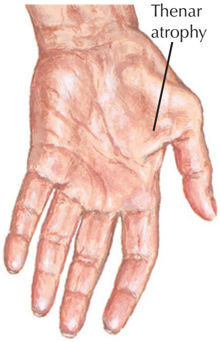
F. Netter M.D.
with
C.A. Luce

de Quervain's Disease



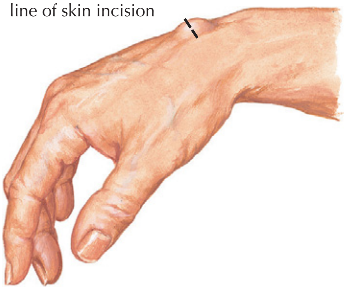
Point of exquisite tenderness over styloid process of radius and sheath of involved tendons

Carpal Tunnel Syndrome



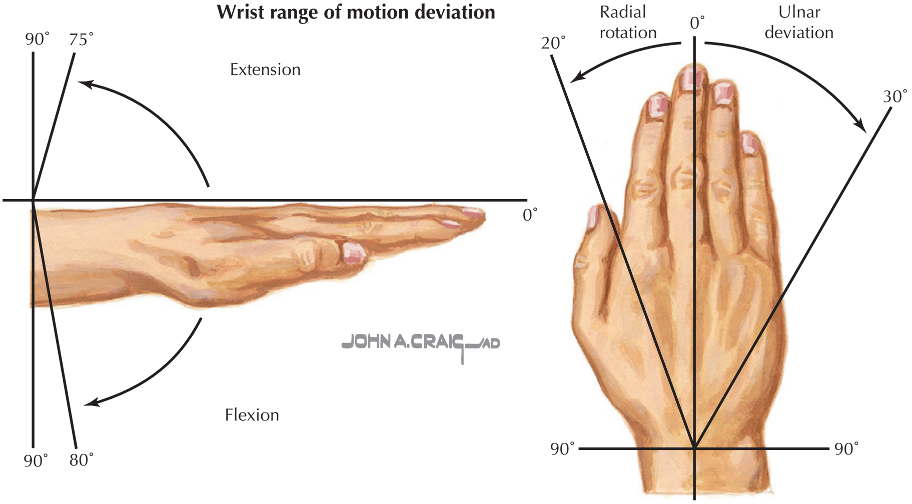
Thenar atrophy

Ganglion Cyst



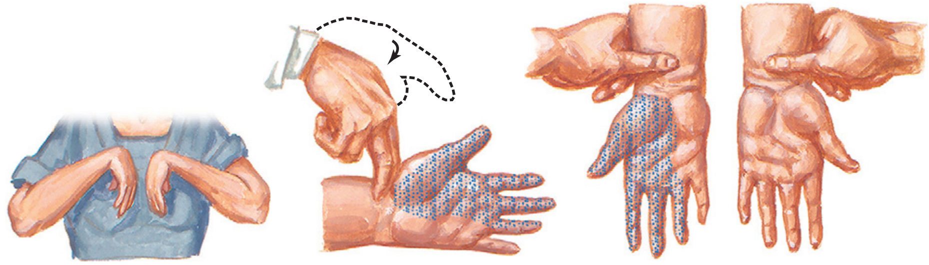
Firm, rubbery, sometimes lobulated swelling over carpus, most prominent on flexion of wrist. Broken line indicates line of skin incision

EXAMINATION	TECHNIQUE	CLINICAL APPLICATION
	INSPECTION	
Gross deformity	Bones and soft tissues	Fractures, dislocations: forearm and wrist
Swelling	Especially dorsal or radial Diffuse	Ganglion cyst Trauma (fracture/dislocation), infection
Wasting	Loss of muscle	Peripheral nerve compression (e.g., CTS)
	PALPATION	
Skin changes	Warm, red Cool, dry	Infection, gout Neurovascular compromise
Radial and ulnar styloids	Palpate each separately	Tenderness may indicate fracture
Carpal bones	Both proximal and distal row Proximal row Pisiform	Snuffbox tenderness: scaphoid fracture; lunate tenderness: Kienböck's disease Scapholunate dissociation Tenderness: pisotriquetral arthritis or FCU tendinitis
Soft tissues	6 dorsal extensor compartments TFCC: distal to ulnar styloid Compartments	Tenderness over 1st compartment: de Quervain's disease Tenderness indicates TFCC injury Firm/tense compartments = compartment synd.



Wrist range of motion deviation

EXAMINATION	TECHNIQUE	CLINICAL APPLICATION
RANGE OF MOTION		
Flex and extend	Flex (toward palm), extend opposite	Normal: flexion 80°, extension 75°
Radial/ulnar deviation	In same plane as the palm	Normal: radial 15-25°, ulnar 30-45°
Pronate and supinate	Flex elbow 90°, rotate wrist	Normal: supinate 90°, pronate 80-90° (only 10-15° in wrist; most motion is in elbow)
NEUROVASCULAR		
Sensory		
Lateral cutaneous nerve of forearm (C6)	Lateral forearm	Deficit indicates corresponding nerve/root lesion
Medial cutaneous nerve of forearm (T1)	Medial forearm	Deficit indicates corresponding nerve/root lesion
Posterior cutaneous nerve of forearm	Posterior forearm	Deficit indicates corresponding nerve/root lesion
Motor		
Radial nerve (C6-7)	Resisted wrist extension	Weakness = ECRL/B or corresponding nerve/root lesion
PIN (C6-7)	Resisted ulnar deviation	Weakness = ECU or corresponding nerve/root lesion
Ulnar nerve (C8)	Resisted wrist flexion	Weakness = FCU or corresponding nerve/root lesion
Median nerve (C7)	Resisted wrist flexion	Weakness = FCR or corresponding nerve/root lesion
Median nerve (C6)	Resisted pronation	Weakness = pronator teres or corresponding nerve/root lesion
Musculocutaneous (C6)	Resisted supination	Weakness = biceps or corresponding nerve/root lesion
Reflex		
C6	Brachioradialis	Hypoactive/absence indicates corresponding radiculopathy
Pulses		
	Radial, ulnar	Diminished/absent = vascular injury or compromise (perform Allen test)



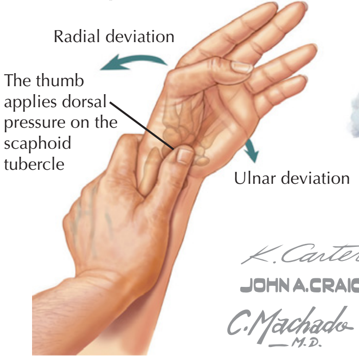
Phalen's test (wrist flexion)

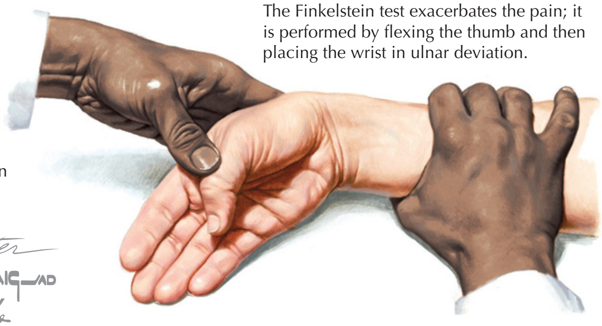
Tinel's sign

Carpal compression test

Provocative tests elicit paresthesias in hand.

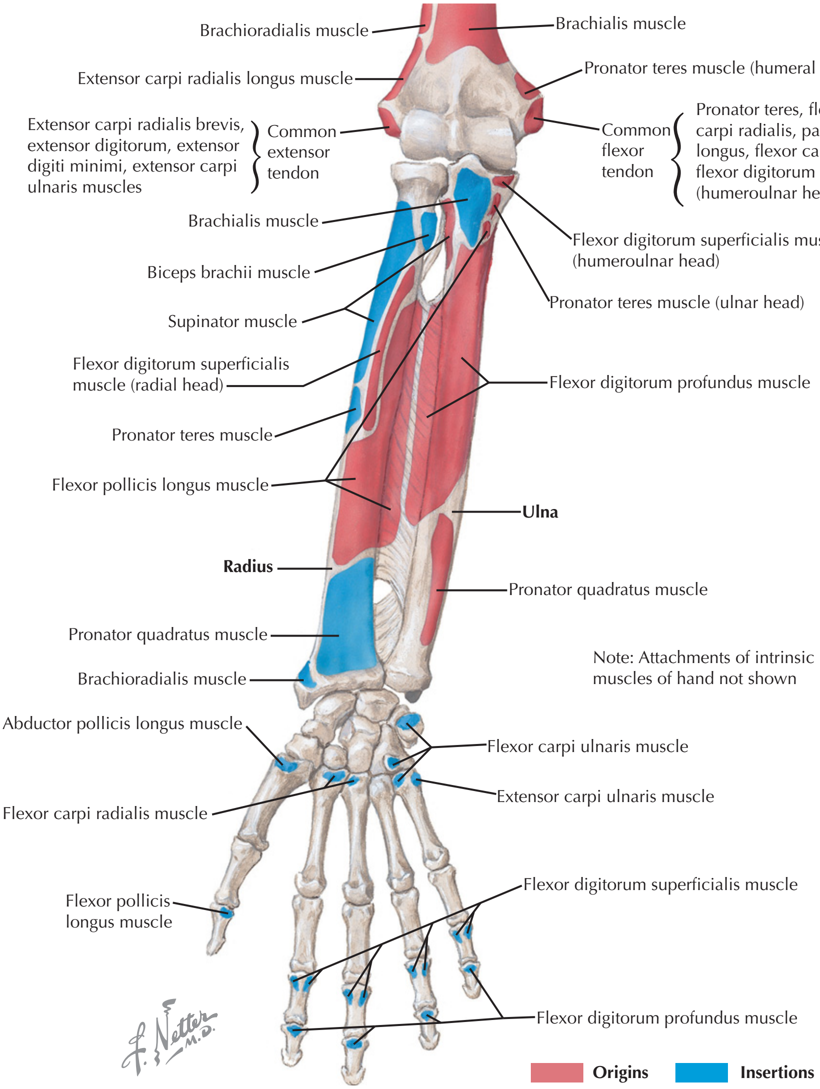
Scaphoid shift test





The Finkelstein test exacerbates the pain; it is performed by flexing the thumb and then placing the wrist in ulnar deviation.

EXAMINATION	TECHNIQUE	CLINICAL APPLICATION / DDX
	SPECIAL TESTS	
Durkan carpal compression	Manual pressure on median nerve at carpal tunnel	Reproduction of symptoms (e.g., tingling, numbness): median nerve compression (most sensitive test for carpal tunnel syndrome [CTS])
Phalen test	Flex both wrists for 1minute	Reproduction of symptoms (e.g., tingling): median n. compression (CTS)
Tinel	Tap volar wrist (CT/TCL)	Reproduction of symptoms (e.g., tingling): median n. compression (CTS)
Finkelstein	Flex thumb into palm, ulnarly deviate the wrist	Pain in 1st dorsal compartment (APL/EPB tendons) suggests de Quervain's tenosynovitis
"Piano key"	Stabilize ulnar and translate radius dorsal and volar	Laxity or subluxation (click) indicates instability of DRUJ
Watson (scaphoid shift)	Push dorsally on distal pole of scaphoid, bring wrist from ulnar to radial deviation	A click or clunk (scaphoid subluxating dorsally over rim of distal radius) is positive for carpal instability (scapholunate dissociation)
Allen test	Occlude both radial and ulnar arteries manually, pump fist, then release one artery only	Delay or absence of "pinking up" of the palm and fingers suggests arterial compromise of the artery released



Anterior (volar)

Brachioradialis muscle
Brachialis muscle
Extensor carpi radialis longus muscle
Pronator teres muscle (humeral head)
Extensor carpi radialis brevis, extensor digitorum, extensor digiti minimi, extensor carpi ulnaris muscles
Common extensor tendon
Common flexor tendon
Pronator teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, flexor digitorum superficialis (humeroulnar head) muscles
Brachialis muscle
Flexor digitorum superficialis muscle (humeroulnar head)
Biceps brachii muscle
Pronator teres muscle (ulnar head)
Supinator muscle
Flexor digitorum superficialis muscle (radial head)
Flexor digitorum profundus muscle
Pronator teres muscle
Flexor pollicis longus muscle
Ulna
Radius
Pronator quadratus muscle
Pronator quadratus muscle
Note: Attachments of intrinsic muscles of hand not shown
Brachioradialis muscle
Abductor pollicis longus muscle
Flexor carpi ulnaris muscle
Extensor carpi ulnaris muscle
Flexor carpi radialis muscle
Flexor digitorum superficialis muscle
Flexor pollicis longus muscle
Flexor digitorum profundus muscle
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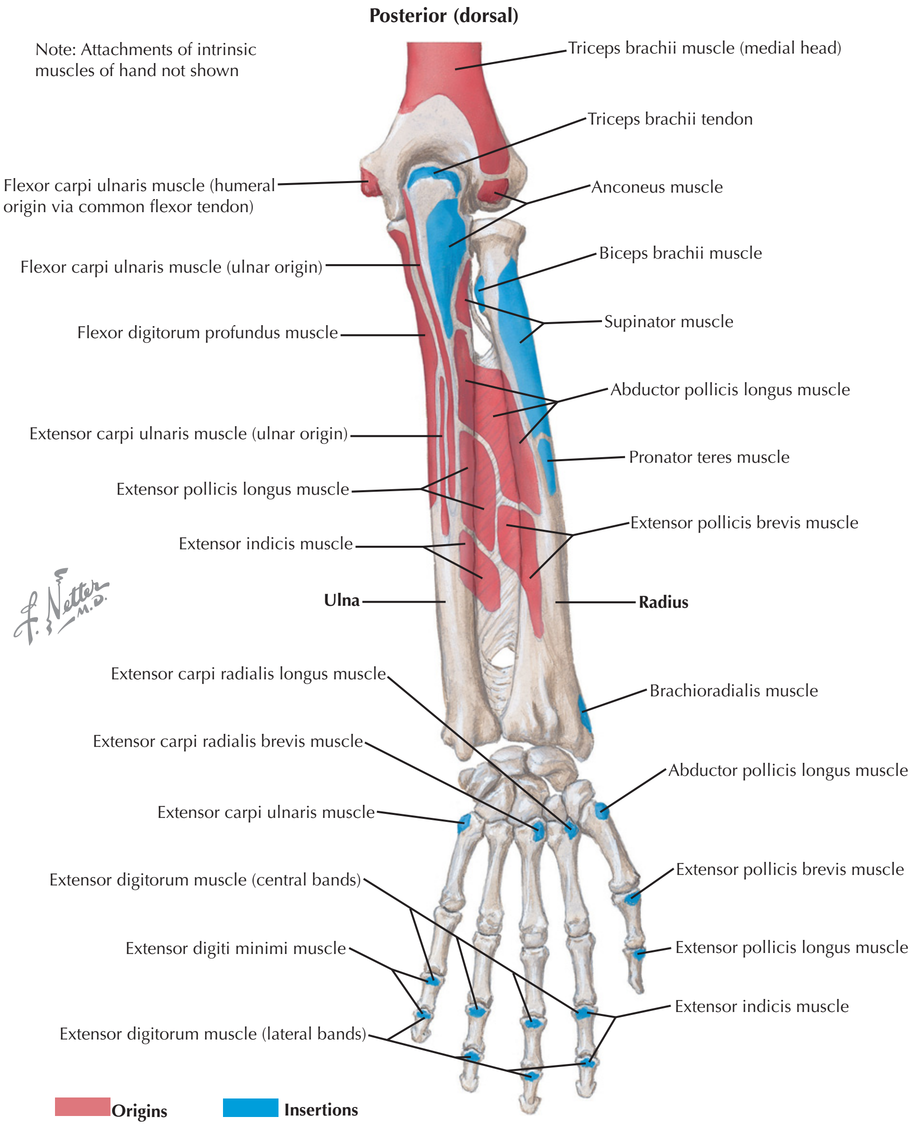
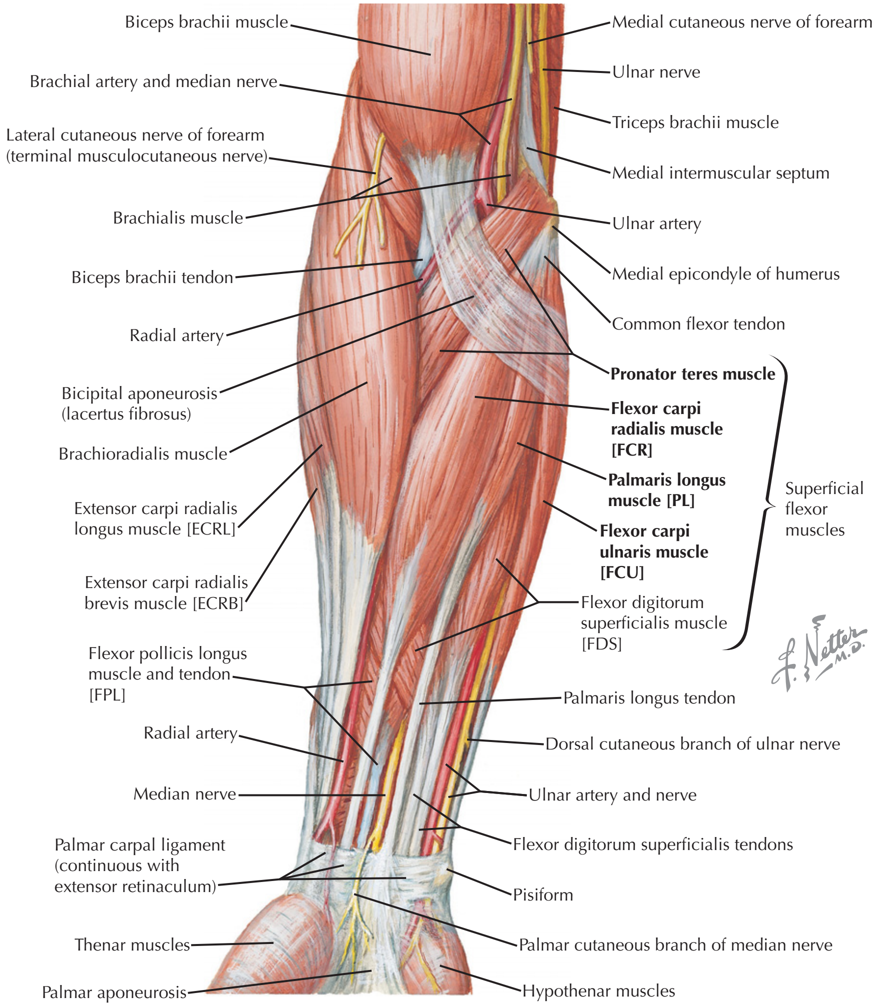
🟥 Origins
🟦 Insertions

PROXIMAL ULNA	PROXIMAL RADIUS
ANTERIOR	
Origins	
Flexor digitorum superficialis (1 head) Pronator teres Supinator Flexor digitorum profundus	Flexor digitorum superficialis (1 head)
Insertions	
Brachialis	Biceps Supinator


Note: Attachments of intrinsic muscles of hand not shown

Posterior (dorsal)
Triceps brachii muscle (medial head)
Triceps brachii tendon
Flexor carpi ulnaris muscle (humeral origin via common flexor tendon)
Anconeus muscle
Flexor carpi ulnaris muscle (ulnar origin)
Biceps brachii muscle
Supinator muscle
Flexor digitorum profundus muscle
Abductor pollicis longus muscle
Extensor carpi ulnaris muscle (ulnar origin)
Pronator teres muscle
Extensor pollicis longus muscle
Extensor pollicis brevis muscle
Extensor indicis muscle
Ulna
Radius
Extensor carpi radialis longus muscle
Brachioradialis muscle
Extensor carpi radialis brevis muscle
Abductor pollicis longus muscle
Extensor carpi ulnaris muscle
Extensor digitorum muscle (central bands)
Extensor pollicis brevis muscle
Extensor digiti minimi muscle
Extensor pollicis longus muscle
Extensor indicis muscle
Extensor digitorum muscle (lateral bands)
Origins
Insertions

PROXIMAL ULNA	PROXIMAL RADIUS
POSTERIOR	
Origins	
Flexor carpi ulnaris Flexor digitorum profundus Supinator	none
Insertions	
Triceps Anconeus	Biceps Supinator


Biceps brachii muscle
Brachial artery and median nerve
Lateral cutaneous nerve of forearm (terminal musculocutaneous nerve)
Brachialis muscle
Biceps brachii tendon
Radial artery
Bicipital aponeurosis (lacertus fibrosus)
Brachioradialis muscle
Extensor carpi radialis longus muscle [ECRL]
Extensor carpi radialis brevis muscle [ECRB]
Flexor pollicis longus muscle and tendon [FPL]
Radial artery
Median nerve
Palmar carpal ligament (continuous with extensor retinaculum)
Thenar muscles
Palmar aponeurosis
Medial cutaneous nerve of forearm
Ulnar nerve
Triceps brachii muscle
Medial intermuscular septum
Ulnar artery
Medial epicondyle of humerus
Common flexor tendon
Pronator teres muscle
Flexor carpi radialis muscle [FCR]
Palmaris longus muscle [PL]
Flexor carpi ulnaris muscle [FCU]
Flexor digitorum superficialis muscle [FDS]
Superficial flexor muscles
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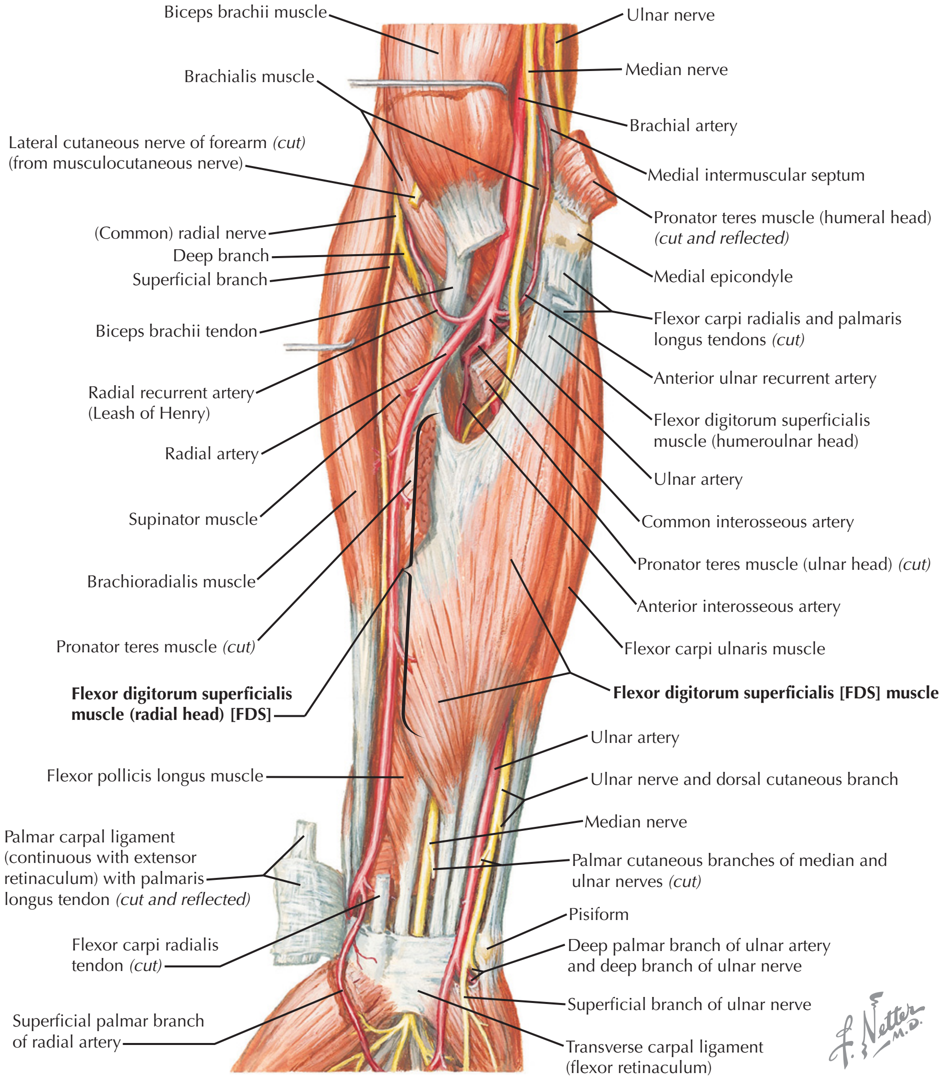
Palmaris longus tendon
Dorsal cutaneous branch of ulnar nerve
Ulnar artery and nerve
Flexor digitorum superficialis tendons
Pisiform
Palmar cutaneous branch of median nerve
Hypothenar muscles

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
SUPERFICIAL FLEXORS					
Pronator teres (PT) Humeral head Ulnar (deep) head	 Medial epicondyle Proximal ulna	Lateral radius middle ⅓	Median	Pronate and flex forearm	Can compress median nerve (pronator syndrome)
Flexor carpi radialis (FCR)	Medial epicondyle	Base of 2nd (and 3rd) metacarpal	Median	Flex wrist, radial deviation	Radial artery is immediately lateral
Palmaris longus (PL)	Medial epicondyle	Flexor retinaculum/ palmar aponeurosis	Median	Flex wrist	Used for tendon transfers, 10% congenitally absent
Flexor carpi ulnaris (FCU)	1. Medial epicondyle 2. Posterior ulna	Pisiform, hook of hamate, 5th MC	Ulnar	Flex wrist, ulnar deviation	Most powerful wrist flexor. May compress ulnar nerve


Biceps brachii muscle
Brachialis muscle
Lateral cutaneous nerve of forearm *(cut)* (from musculocutaneous nerve)
(Common) radial nerve
Deep branch
Superficial branch
Biceps brachii tendon
Radial recurrent artery (Leash of Henry)
Radial artery
Supinator muscle
Brachioradialis muscle
Pronator teres muscle *(cut)*
Flexor digitorum superficialis muscle (radial head) [FDS]
Flexor pollicis longus muscle
Palmar carpal ligament (continuous with extensor retinaculum) with palmaris longus tendon *(cut and reflected)*
Flexor carpi radialis tendon *(cut)*
Superficial palmar branch of radial artery
Ulnar nerve
Median nerve
Brachial artery
Medial intermuscular septum
Pronator teres muscle (humeral head) *(cut and reflected)*
Medial epicondyle
Flexor carpi radialis and palmaris longus tendons *(cut)*
Anterior ulnar recurrent artery
Flexor digitorum superficialis muscle (humeroulnar head)
Ulnar artery
Common interosseous artery
Pronator teres muscle (ulnar head) *(cut)*
Anterior interosseous artery
Flexor carpi ulnaris muscle
Flexor digitorum superficialis [FDS] muscle
Ulnar artery
Ulnar nerve and dorsal cutaneous branch
Median nerve
Palmar cutaneous branches of median and ulnar nerves *(cut)*
Pisiform
Deep palmar branch of ulnar artery and deep branch of ulnar nerve
Superficial branch of ulnar nerve
Transverse carpal ligament (flexor retinaculum)
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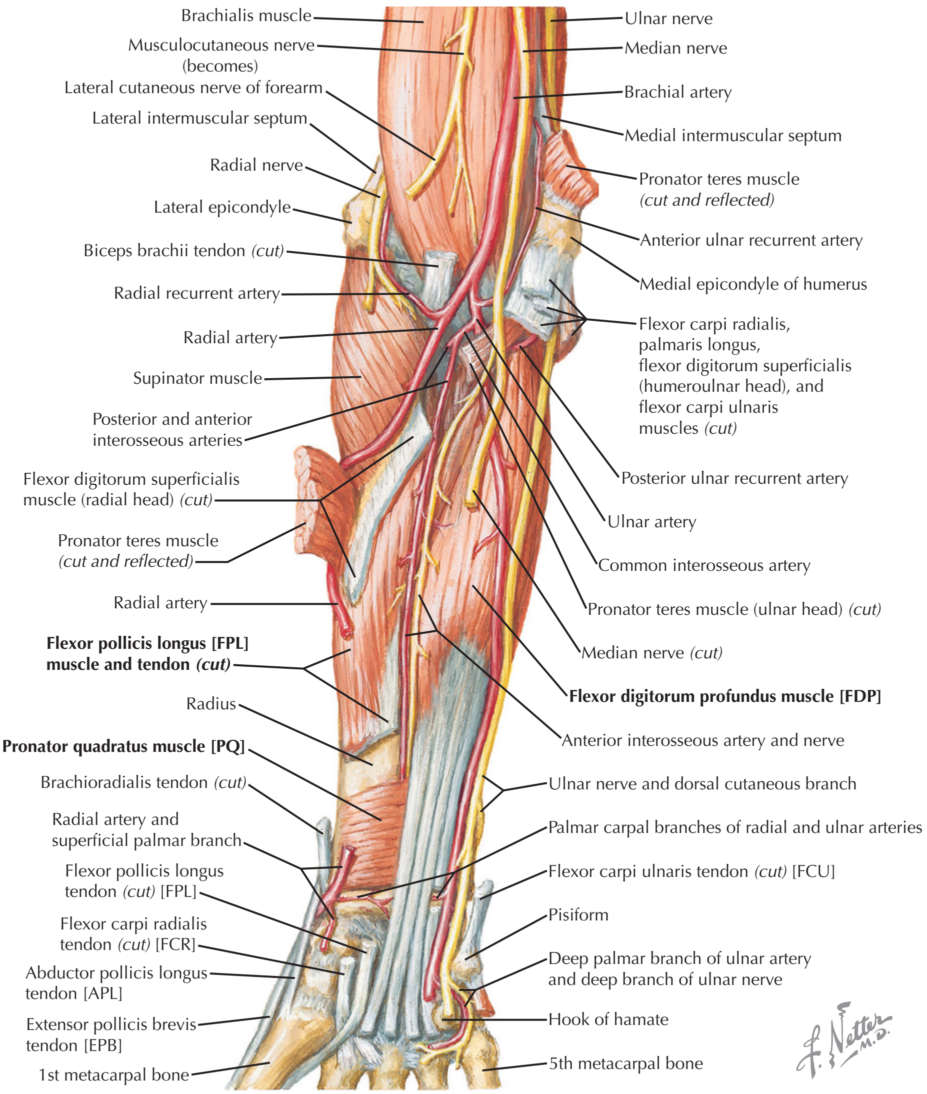
MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
SUPERFICIAL FLEXORS					
Flexor digitorum superficialis (FDS)	1. Medial epicondyle proximal ulna 2. Anteroproximal radius	Middle phalanges of digits (not thumb)	Median	Flex PIPJ (also flex digit and wrist)	Sublimus test will isolate and test function
FDS is often considered a "middle flexor" because of its position between muscles.					


Brachialis muscle
Musculocutaneous nerve (becomes)
Lateral cutaneous nerve of forearm
Lateral intermuscular septum
Radial nerve
Lateral epicondyle
Biceps brachii tendon *(cut)*
Radial recurrent artery
Radial artery
Supinator muscle
Posterior and anterior interosseous arteries
Flexor digitorum superficialis muscle (radial head) *(cut)*
Pronator teres muscle *(cut and reflected)*
Radial artery
Flexor pollicis longus [FPL] muscle and tendon *(cut)*
Radius
Pronator quadratus muscle [PQ]
Brachioradialis tendon *(cut)*
Radial artery and superficial palmar branch
Flexor pollicis longus tendon *(cut)* [FPL]
Flexor carpi radialis tendon *(cut)* [FCR]
Abductor pollicis longus tendon [APL]
Extensor pollicis brevis tendon [EPB]
1st metacarpal bone
Ulnar nerve
Median nerve
Brachial artery
Medial intermuscular septum
Pronator teres muscle *(cut and reflected)*
Anterior ulnar recurrent artery
Medial epicondyle of humerus
Flexor carpi radialis, palmaris longus, flexor digitorum superficialis (humeroulnar head), and flexor carpi ulnaris muscles *(cut)*
Posterior ulnar recurrent artery
Ulnar artery
Common interosseous artery
Pronator teres muscle (ulnar head) *(cut)*
Median nerve *(cut)*
Flexor digitorum profundus muscle [FDP]
Anterior interosseous artery and nerve
Ulnar nerve and dorsal cutaneous branch
Palmar carpal branches of radial and ulnar arteries
Flexor carpi ulnaris tendon *(cut)* [FCU]
Pisiform
Deep palmar branch of ulnar artery and deep branch of ulnar nerve
Hook of hamate
5th metacarpal bone
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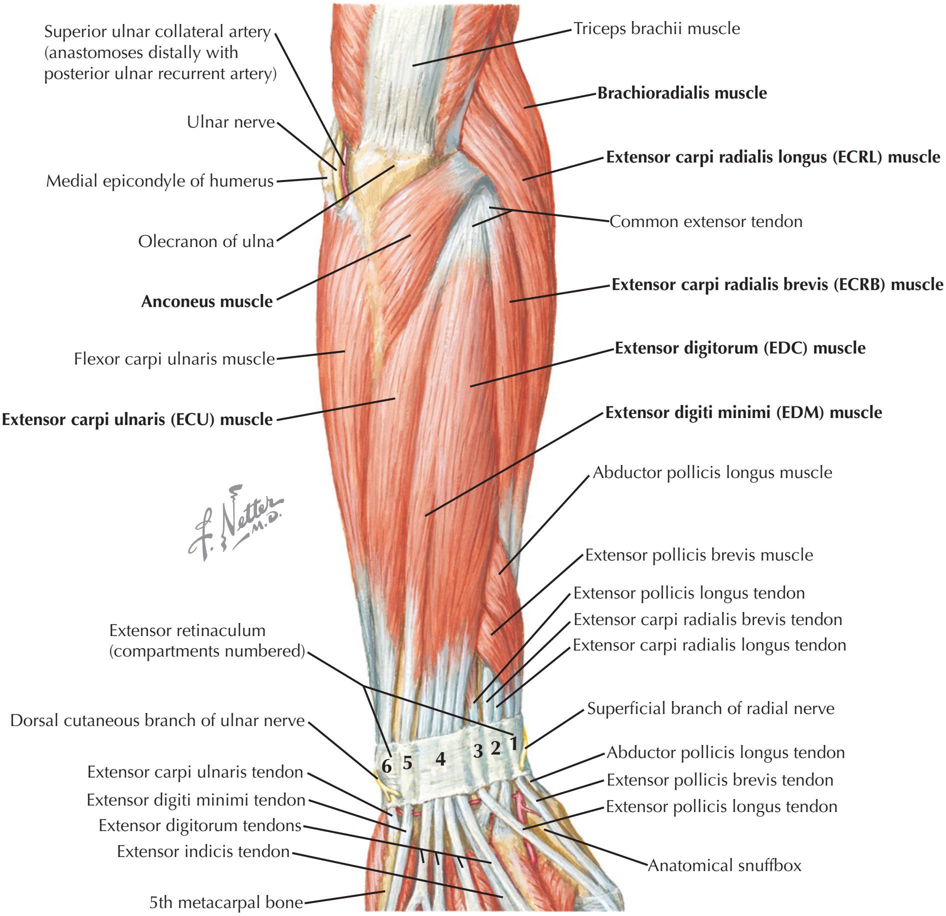
MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
DEEP FLEXORS					
Flexor digitorum profundus (FDP)	Anterior ulna & interosseous membrane	Distal phalanx (IF, +/– MF) Distal phalanx (RF, SF, +/– MF)	Median/AIN Ulnar	Flex DIPJ (also flex digit and wrist)	Avulsion: Jersey finger Profundus test will isolate and test function
Flexor pollicis longus (FPL)	Anterior radius & proximal ulna	Distal phalanx of thumb	Median/AIN	Flex thumb IP	FDP and FPL are most susceptible to Volkmann's contracture
Pronator quadratus (PQ)	Medial distal ulna	Anterior distal radius	Median/AIN	Pronate forearm	Primary pronator (initiates pronation)

- AIN innervates all three deep flexors. It is tested by making "OK" signs.


Superior ulnar collateral artery (anastomoses distally with posterior ulnar recurrent artery)
Ulnar nerve
Medial epicondyle of humerus
Olecranon of ulna
Anconeus muscle
Flexor carpi ulnaris muscle
Extensor carpi ulnaris (ECU) muscle
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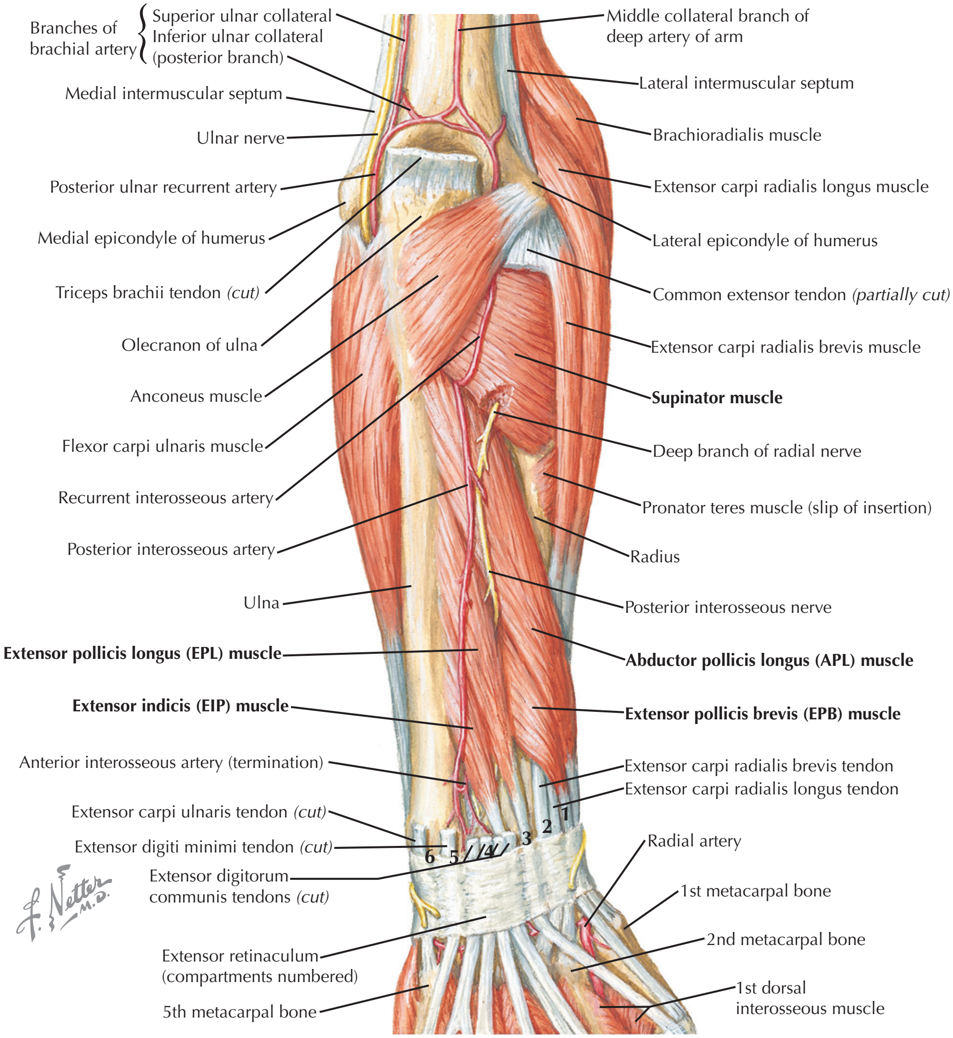
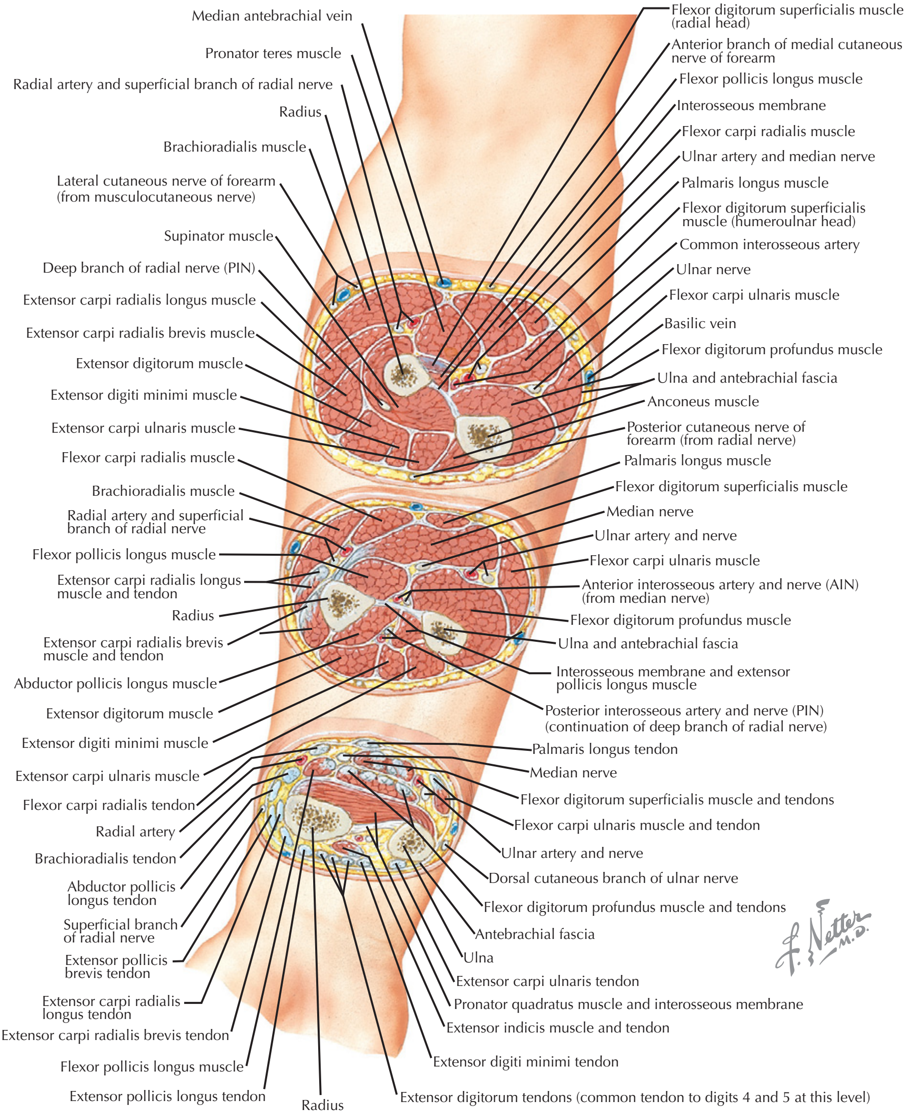
Extensor retinaculum (compartments numbered)
Dorsal cutaneous branch of ulnar nerve
Extensor carpi ulnaris tendon
Extensor digiti minimi tendon
Extensor digitorum tendons
Extensor indicis tendon
5th metacarpal bone
6
5
4
3
2
1
Triceps brachii muscle
Brachioradialis muscle
Extensor carpi radialis longus (ECRL) muscle
Common extensor tendon
Extensor carpi radialis brevis (ECRB) muscle
Extensor digitorum (EDC) muscle
Extensor digiti minimi (EDM) muscle
Abductor pollicis longus muscle
Extensor pollicis brevis muscle
Extensor pollicis longus tendon
Extensor carpi radialis brevis tendon
Extensor carpi radialis longus tendon
Superficial branch of radial nerve
Abductor pollicis longus tendon
Extensor pollicis brevis tendon
Extensor pollicis longus tendon
Anatomical snuffbox

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
		SUPERFICIAL EXTENSORS			
Anconeus	Posterior-lateral epicondyle	Posterior-proximal ulna	Radial	Forearm extension	Muscular plane in Kocher approach
Extensor digitorum communis (EDC)	Lateral epicondyle	MCP: Sag. band P2: Central slip P3: Term. insert	Radial-PIN	Digit extension	Tendon avulsion: P2: boutonniere P3: mallet finger
Extensor digiti minimi (EDM)	Lateral epicondyle	Same as above in small finger	Radial-PIN	SF extension	Aka EDQ: In 5th dorsal compartment
Extensor carpi ulnaris (ECU)	Lateral epicondyle	Base of 5th MC	Radial-PIN	Hand extension and adduction	Can cause painful snapping over ulna
		Mobile Wad			
Brachioradialis (BR)	Lateral condyle	Lateral distal radius	Radial	Forearm flexion	Is a deforming force in radius fractures
Extensor carpi radialis longus	Lateral condyle	Base of 2nd MC	Radial	Wrist extension	Aka ECRL
Extensor carpi radialis brevis	Lateral epicondyle	Base of 3rd MC	Radial-PIN	Wrist extension	ECRB degenerates in tennis elbow


Branches of brachial artery
Superior ulnar collateral
Inferior ulnar collateral (posterior branch)
Medial intermuscular septum
Ulnar nerve
Posterior ulnar recurrent artery
Medial epicondyle of humerus
Triceps brachii tendon (cut)
Olecranon of ulna
Anconeus muscle
Flexor carpi ulnaris muscle
Recurrent interosseous artery
Posterior interosseous artery
Ulna
Extensor pollicis longus (EPL) muscle
Extensor indicis (EIP) muscle
Anterior interosseous artery (termination)
Extensor carpi ulnaris tendon (cut)
Extensor digiti minimi tendon (cut)
Extensor digitorum communis tendons (cut)
Extensor retinaculum (compartments numbered)
5th metacarpal bone
Middle collateral branch of deep artery of arm
Lateral intermuscular septum
Brachioradialis muscle
Extensor carpi radialis longus muscle
Lateral epicondyle of humerus
Common extensor tendon (partially cut)
Extensor carpi radialis brevis muscle
Supinator muscle
Deep branch of radial nerve
Pronator teres muscle (slip of insertion)
Radius
Posterior interosseous nerve
Abductor pollicis longus (APL) muscle
Extensor pollicis brevis (EPB) muscle
Extensor carpi radialis brevis tendon
Extensor carpi radialis longus tendon
Radial artery
1st metacarpal bone
2nd metacarpal bone
1st dorsal interosseous muscle
1
2
3
4
5
6

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
DEEP EXTENSORS					
Supinator	Posterior medial ulna	Proximal lateral radius	Radial-PIN	Forearm supination	PIN pierces muscles, can be compressed
Abductor pollicis longus (APL)	Posterior radius/ ulna	Base of 1st thumb metacarpal	Radial-PIN	Abduct and extend thumb (CMCJ)	de Quervain's disease (may have multiple slips)
Extensor pollicis brevis (EPB)	Posterior radius	Base of thumb prox. phalanx	Radial-PIN	Extend thumb (MCPJ)	Radial border of snuffbox
Extensor pollicis longus (EPL)	Posterior ulna	Base of thumb distal phalanx	Radial-PIN	Extend thumb (IPJ)	Tendon turns 45° on Lister's tubercle
Extensor indicis proprius (EIP)	Posterior ulna	Same as EDC & EDM	Radial-PIN	Index finger extension	Ulnar to EDC tendon; last PIN muscle


Median antebrachial vein
Pronator teres muscle
Radial artery and superficial branch of radial nerve
Radius
Brachioradialis muscle
Lateral cutaneous nerve of forearm (from musculocutaneous nerve)
Supinator muscle
Deep branch of radial nerve (PIN)
Extensor carpi radialis longus muscle
Extensor carpi radialis brevis muscle
Extensor digitorum muscle
Extensor digiti minimi muscle
Extensor carpi ulnaris muscle
Flexor carpi radialis muscle
Brachioradialis muscle
Radial artery and superficial branch of radial nerve
Flexor pollicis longus muscle
Extensor carpi radialis longus muscle and tendon
Radius
Extensor carpi radialis brevis muscle and tendon
Abductor pollicis longus muscle
Extensor digitorum muscle
Extensor digiti minimi muscle
Extensor carpi ulnaris muscle
Flexor carpi radialis tendon
Radial artery
Brachioradialis tendon
Abductor pollicis longus tendon
Superficial branch of radial nerve
Extensor pollicis brevis tendon
Extensor carpi radialis longus tendon
Extensor carpi radialis brevis tendon
Flexor pollicis longus muscle
Extensor pollicis longus tendon
Radius
Flexor digitorum superficialis muscle (radial head)
Anterior branch of medial cutaneous nerve of forearm
Flexor pollicis longus muscle
Interosseous membrane
Flexor carpi radialis muscle
Ulnar artery and median nerve
Palmaris longus muscle
Flexor digitorum superficialis muscle (humeroulnar head)
Common interosseous artery
Ulnar nerve
Flexor carpi ulnaris muscle
Basilic vein
Flexor digitorum profundus muscle
Ulna and antebrachial fascia
Anconeus muscle
Posterior cutaneous nerve of forearm (from radial nerve)
Palmaris longus muscle
Flexor digitorum superficialis muscle
Median nerve
Ulnar artery and nerve
Flexor carpi ulnaris muscle
Anterior interosseous artery and nerve (AIN) (from median nerve)
Flexor digitorum profundus muscle
Ulna and antebrachial fascia
Interosseous membrane and extensor pollicis longus muscle
Posterior interosseous artery and nerve (PIN) (continuation of deep branch of radial nerve)
Palmaris longus tendon
Median nerve
Flexor digitorum superficialis muscle and tendons
Flexor carpi ulnaris muscle and tendon
Ulnar artery and nerve
Dorsal cutaneous branch of ulnar nerve
Flexor digitorum profundus muscle and tendons
Antebrachial fascia
Ulna
Extensor carpi ulnaris tendon
Pronator quadratus muscle and interosseous membrane
Extensor indicis muscle and tendon
Extensor digiti minimi tendon
Extensor digitorum tendons (common tendon to digits 4 and 5 at this level)
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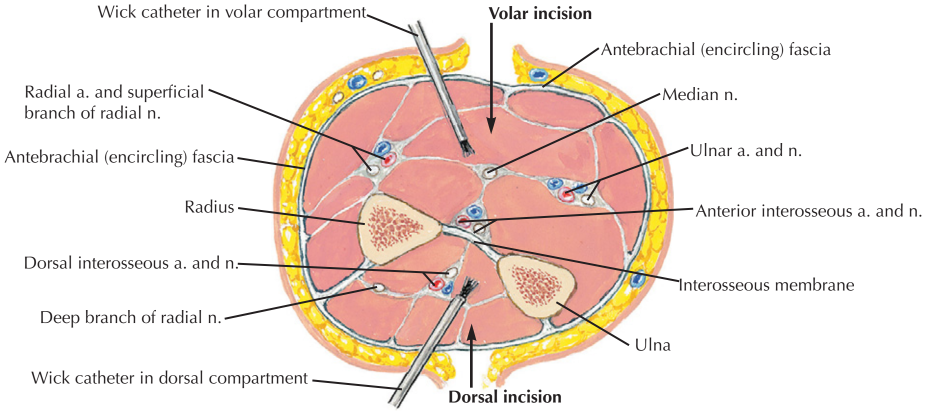
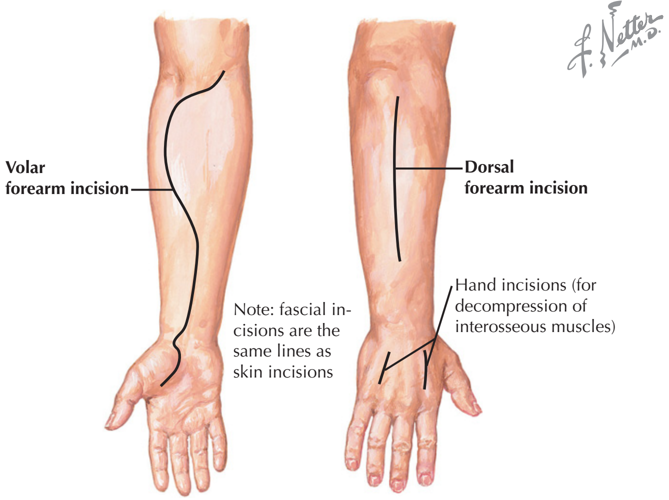
STRUCTURE	RELATIONSHIP
RELATIONSHIPS	
Ulnar nerve/artery	Run under FDS on top of FDP muscles, ulnar to the artery
Superior radial nerve	Runs under the brachioradialis muscle/tendon, radial to the artery
Radial artery	Is radial (lateral) to FCR muscle and tendon
Median nerve	Is radial (lateral) to ulnar nerve, runs between FDP and FPL muscles into the carpal tunnel
Post. interosseous nerve (PIN)	Pierces supinator muscle proximally, runs between APL & EPL along interosseous membrane

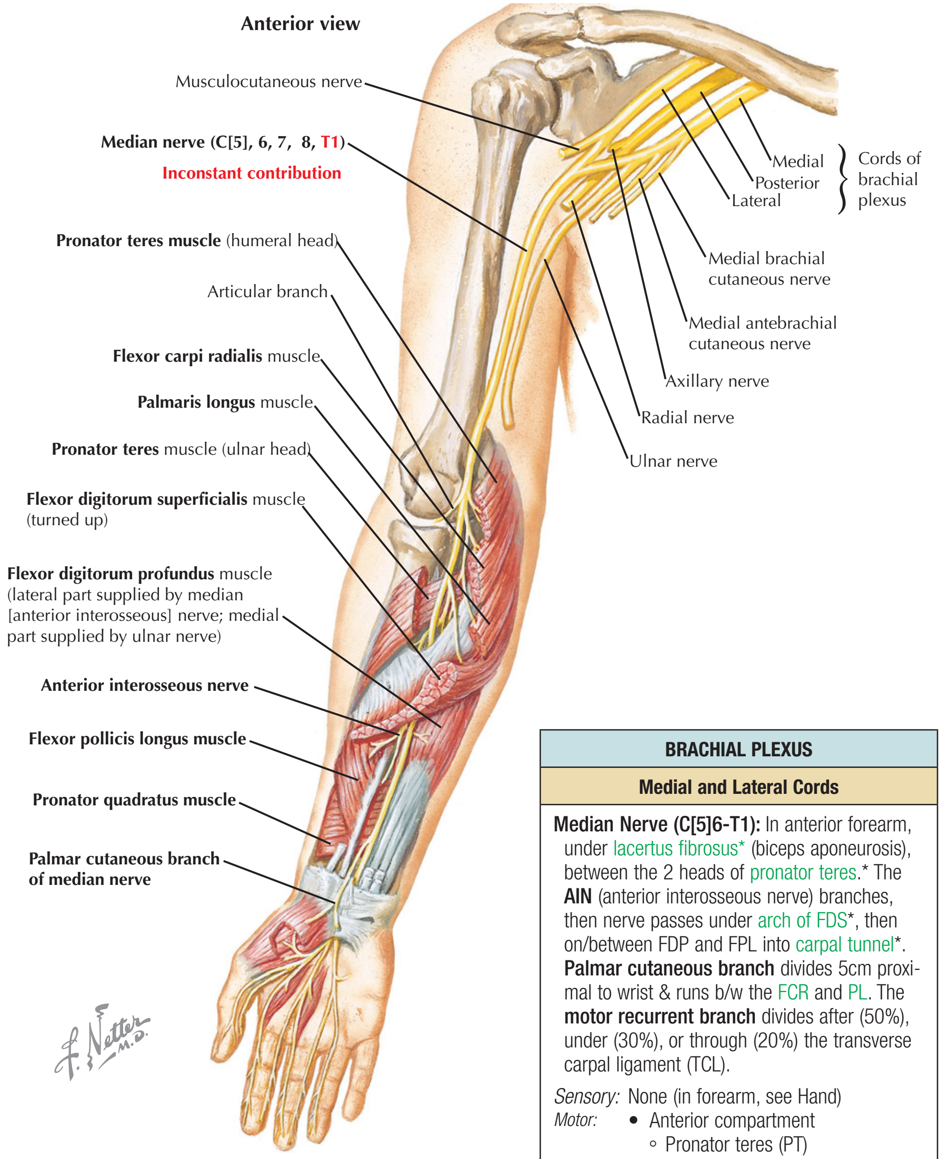
Incisions for Compartment Syndrome of Forearm and Hand


Wick catheter in volar compartment
Volar incision
Antebrachial (encircling) fascia
Radial a. and superficial branch of radial n.
Median n.
Antebrachial (encircling) fascia
Ulnar a. and n.
Radius
Anterior interosseous a. and n.
Dorsal interosseous a. and n.
Interosseous membrane
Deep branch of radial n.
Ulna
Wick catheter in dorsal compartment
Dorsal incision

Section through midforearm


Volar forearm incision
Dorsal forearm incision
Note: fascial incisions are the same lines as skin incisions
Hand incisions (for decompression of interosseous muscles)
F. Netter M.D.

STRUCTURE	CONTENTS
COMPARTMENTS	
Anterior	
Superficial	Pronator teres (PT), flexor carpi radialis (FCR), palmaris longus (PL), flexor carpi ulnaris (FCU)
Middle	Flexor digitorum superficialis (FDS)
Deep	Flexor digitorum profundus (FDP), flexor pollicis longus (FPL), pronator quadratus (PQ)
Posterior	
Superficial	Anconeus, ext. digit. communis (EDC), ext. digit. minimi (EDM), ext. carpi ulnaris (ECU)
Deep	Supinator, abd. poll. longus (APL), ext. poll. brevis (EPB), ext. poll. longus (EPL), ext. indicis proprius (EIP)
Mobile Wad	
	Brachioradialis, extensor carpi radialis longus (ECRL), extensor carpi radialis brevis (ECRB)
FASCIOTOMIES	
Palmar incision	Releases the entire anterior compartment
Dorsal incision	Releases the entire posterior compartment and mobile wad


Anterior view
Musculocutaneous nerve
Median nerve (C[5], 6, 7, 8, T1)
Inconstant contribution
Pronator teres muscle (humeral head)
Articular branch
Flexor carpi radialis muscle
Palmaris longus muscle
Pronator teres muscle (ulnar head)
Flexor digitorum superficialis muscle (turned up)
Flexor digitorum profundus muscle (lateral part supplied by median [anterior interosseous] nerve; medial part supplied by ulnar nerve)
Anterior interosseous nerve
Flexor pollicis longus muscle
Pronator quadratus muscle
Palmar cutaneous branch of median nerve
Medial
Posterior
Lateral
Cords of brachial plexus
Medial brachial cutaneous nerve
Medial antebrachial cutaneous nerve
Axillary nerve
Radial nerve
Ulnar nerve

BRACHIAL PLEXUS

Medial and Lateral Cords

Median Nerve (C[5]6-T1): In anterior forearm, under lacertus fibrosus* (biceps aponeurosis), between the 2 heads of pronator teres.* The **AIN** (anterior interosseous nerve) branches, then nerve passes under arch of FDS*, then on/between FDP and FPL into carpal tunnel*. **Palmar cutaneous branch** divides 5cm proximal to wrist & runs b/w the FCR and PL. The **motor recurrent branch** divides after (50%), under (30%), or through (20%) the transverse carpal ligament (TCL).

Sensory: None (in forearm, see Hand)

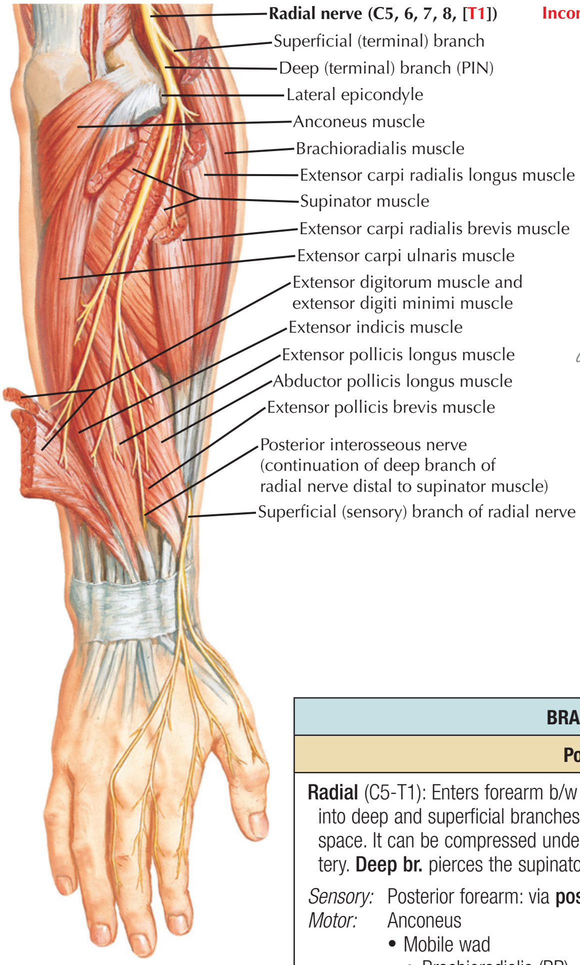
Motor:
- Anterior compartment
  - Pronator teres (PT)
  - Flexor carpi radialis (FCR)
  - Palmaris longus (PL)
  - Flexor dig. super. (FDS)

Anterior Interosseous Nerve (AIN): Branches proximally, then runs along the interosseous membrane with anterior interosseous artery, between FPL & FDP

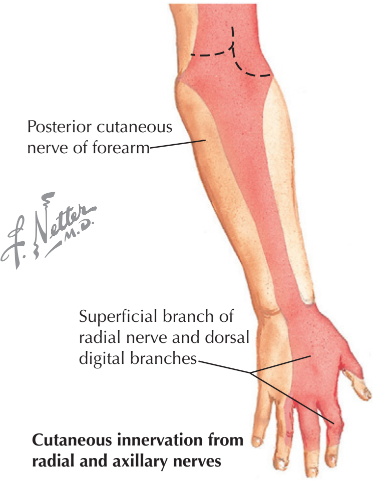
Sensory: Volar wrist capsule

Motor:
- Anterior compartment—deep flexors
  - Flexor digitorum profundus (FDP) to 2nd (3rd) digits
  - Flexor pollicis longus (FPL)
  - Pronator quadratus (PQ)

*Potential site of nerve compression.


Radial nerve (C5, 6, 7, 8, [T1])
Inconstant contribution
Superficial (terminal) branch
Deep (terminal) branch (PIN)
Lateral epicondyle
Anconeus muscle
Brachioradialis muscle
Extensor carpi radialis longus muscle
Supinator muscle
Extensor carpi radialis brevis muscle
Extensor carpi ulnaris muscle
Extensor digitorum muscle and extensor digiti minimi muscle
Extensor indicis muscle
Extensor pollicis longus muscle
Abductor pollicis longus muscle
Extensor pollicis brevis muscle
Posterior interosseous nerve (continuation of deep branch of radial nerve distal to supinator muscle)
Superficial (sensory) branch of radial nerve

Posterior view


Posterior cutaneous nerve of forearm
Superficial branch of radial nerve and dorsal digital branches

Cutaneous innervation from radial and axillary nerves

BRACHIAL PLEXUS

Posterior Cord

Radial (C5-T1): Enters forearm b/w brachioradialis (BR) & brachialis, then divides into deep and superficial branches. **Superficial br.** runs under BR to thumb web space. It can be compressed under the BR tendon.* It is lateral to the radial artery. **Deep br.** pierces the supinator, then becomes the **PIN.**

Sensory: Posterior forearm: via **posterior cutaneous nerve of forearm**

Motor: Anconeus

- Mobile wad
  - Brachioradialis (BR)
  - Extensor carpi radialis longus (ECRL)

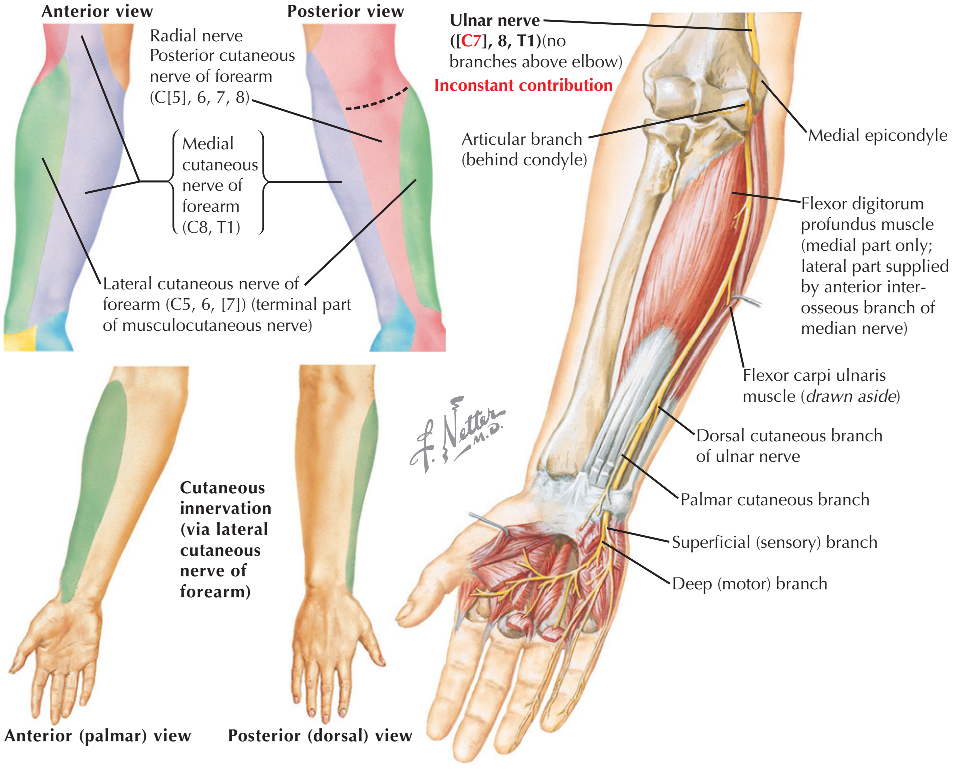
Posterior Interrosseous Nerve (PIN): Runs past vascular Leash of Henry* (recurrent radial artery) and ECRB, through the arcade of Frohse* (proximal supinator), into the supinator, past its distal edge,* then along interosseous membrane under EDC and between APL and EPL.

Sensory: Dorsal wrist capsule (in 4th dorsal compartment)

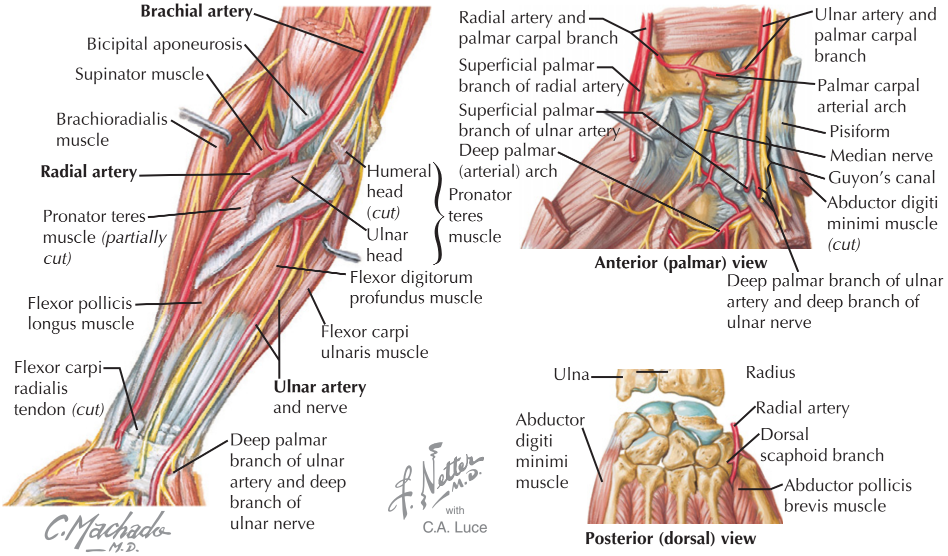
Motor:

- Mobile wad
  - Extensor carpi radialis brevis (ECRB)
- Posterior compartment—superficial extensors
  - Supinator
  - Extensor digitorum communis (EDC)
  - Extensor digiti minimi (EDM or EDQ)
  - Extensor carpi ulnaris (ECU)
- Posterior compartment—deep extensors
  - Abductor pollicis longus (APL)
  - Extensor pollicis brevis (EPB)
  - Extensor pollicis longus (EPL)
  - Extensor indicis proprius (EIP)

*Potential site of nerve compression.


Anterior view
Posterior view
Radial nerve
Posterior cutaneous nerve of forearm (C[5], 6, 7, 8)
Medial cutaneous nerve of forearm (C8, T1)
Lateral cutaneous nerve of forearm (C5, 6, [7]) (terminal part of musculocutaneous nerve)
Cutaneous innervation (via lateral cutaneous nerve of forearm)
Anterior (palmar) view
Posterior (dorsal) view
Ulnar nerve ([C7], 8, T1)(no branches above elbow)
Inconstant contribution
Articular branch (behind condyle)
Medial epicondyle
Flexor digitorum profundus muscle (medial part only; lateral part supplied by anterior interosseous branch of median nerve)
Flexor carpi ulnaris muscle (*drawn aside*)
Dorsal cutaneous branch of ulnar nerve
Palmar cutaneous branch
Superficial (sensory) branch
Deep (motor) branch
F. Netter M.D.

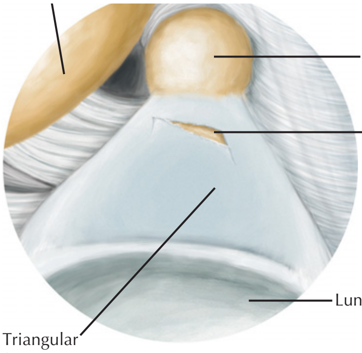
BRACHIAL PLEXUS
Lateral Cord
Musculocutaneous (C5-7): Exits between biceps & brachialis, purely sensory, runs in subcutaneous tissues above the brachioradialis *Sensory:* Radial forearm: via **lateral cutaneous nerve of forearm** *Motor:* None (in forearm)
MEDIAL CORD
Medial Cutaneous Nerve of Forearm (Antebrachial Cutaneous) (C8-T1): Branches directly from the cord, runs subcutaneously anterior to medial epicondyle into the medial forearm *Sensory:* Medial forearm *Motor:* None
Ulnar (C[7]8-T1): Runs posterior to medial epicondyle in cubital tunnel,* then through FCU heads/aponeurosis,* then runs on FDP (under FDS) to wrist. The **dorsal** and **palmar cutaneous branches** divide 4-5cm proximal to wrist, then the nerve runs into the ulnar tunnel (Guyon's canal*), where it divides into deep/**motor** & superficial/**sensory branches** *Sensory:* None (in forearm) *Motor:* • Anterior compartment ◦ Flexor carpi ulnaris (FCU) ◦ Flexor digitorum profundus (FDP) to (3rd), 4th, 5th digits
*Potential site of nerve compression.

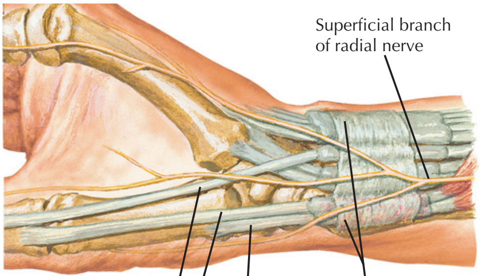

Brachial artery
Bicipital aponeurosis
Supinator muscle
Brachioradialis muscle
Radial artery
Pronator teres muscle (partially cut)
Flexor pollicis longus muscle
Flexor carpi radialis tendon (cut)
Humeral head (cut)
Ulnar head
Pronator teres muscle
Flexor digitorum profundus muscle
Flexor carpi ulnaris muscle
Ulnar artery and nerve
Deep palmar branch of ulnar artery and deep branch of ulnar nerve
C. Machado M.D.
F. Netter M.D. with C.A. Luce
Radial artery and palmar carpal branch
Superficial palmar branch of radial artery
Superficial palmar branch of ulnar artery
Deep palmar (arterial) arch
Ulnar artery and palmar carpal branch
Palmar carpal arterial arch
Pisiform
Median nerve
Guyon's canal
Abductor digiti minimi muscle (cut)
Deep palmar branch of ulnar artery and deep branch of ulnar nerve
Ulna
Radius
Abductor digiti minimi muscle
Radial artery
Dorsal scaphoid branch
Abductor pollicis brevis muscle

Anterior (palmar) view

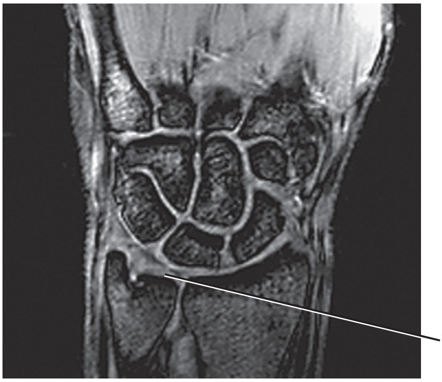
Posterior (dorsal) view

COURSE	BRANCHES	
FOREARM		
Radial Artery		
Runs over the pronator teres, on FDS & FPL lateral to the FCR	Radial recurrent (leash of Henry) Muscular branches	
Ulnar Artery		
Runs under the ulnar head of the pronator teres, on the FDP muscle, lateral and adjacent to the ulnar nerve	Anterior ulnar recurrent Posterior ulnar recurrent Common interosseous ∘ Anterior interosseous ∘ Posterior interosseous ∘ Recurrent interosseous Muscular branches	
WRIST		
Radial Artery		
Lateral to FCR tendon, wraps dorsally, under the APL & EPB tendons, between the 2 heads of 1st dorsal interosseous muscles, to the palm ending in deep arch	Palmar carpal branch Dorsal carpal branch **Superficial palmar branch** ∘ Palmar scaphoid branch Dorsal scaphoid branch **Deep palmar arch**	Deep to flexor tendons Deep to extensor tendons Anastomoses w/super. palmar arch Supplies 25% of scaphoid (distal) Supplies 75% of scaphoid (proximal) Terminal branch of radial artery in hand
Ulnar Artery		
On transverse carpal ligament (TCL) into Guyon's canal, divides into deep and superficial palmar branches	Palmar carpal branch Dorsal carpal branch **Deep palmar** branch **Superficial palmar arch**	Deep to flexor tendons Deep to extensor tendons Anastomoses with deep palmar arch Terminal branch of the *ulnar* artery
• Allen test: Occlude both radial and ulnar arteries at the wrist. Patient squeezes fist to exsanguinate the hand. Release one artery and check for hand perfusion. Repeat with the other artery. Test confirms patency of arches/vessels.		


Ulnar styloid
TFCC tear
Lunate fossa
Triangular fibrocartilage (disc)

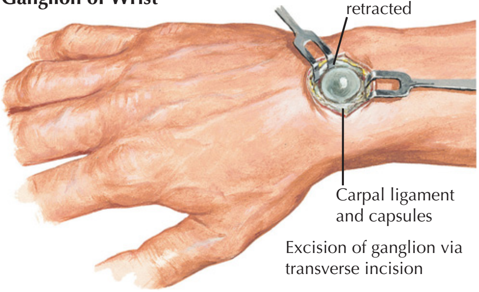

Superficial branch of radial nerve
Extensor pollicis longus, extensor pollicis brevis, abductor pollicis longus tendons
Extensor retinaculum

Course of abductor pollicis longus and extensor pollicis brevis tendons through 1st compartment of extensor retinaculum



Triangular fibrocartilage tear (TFCC)

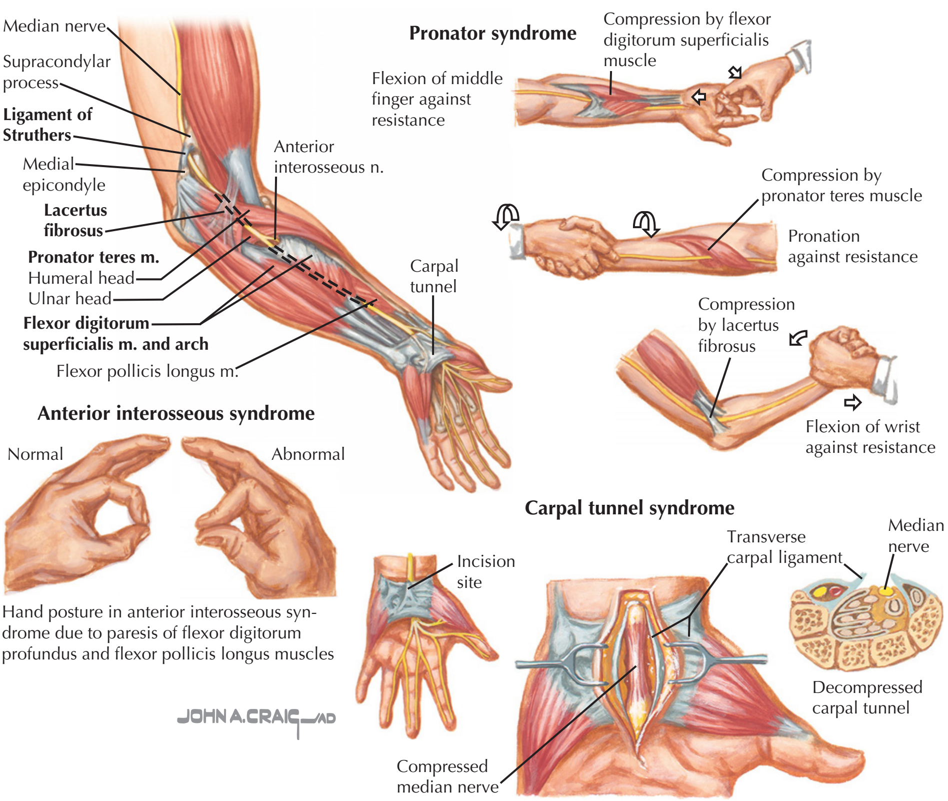
Ganglion of Wrist


Extensor tendon retracted
Carpal ligament and capsules

Excision of ganglion via transverse incision

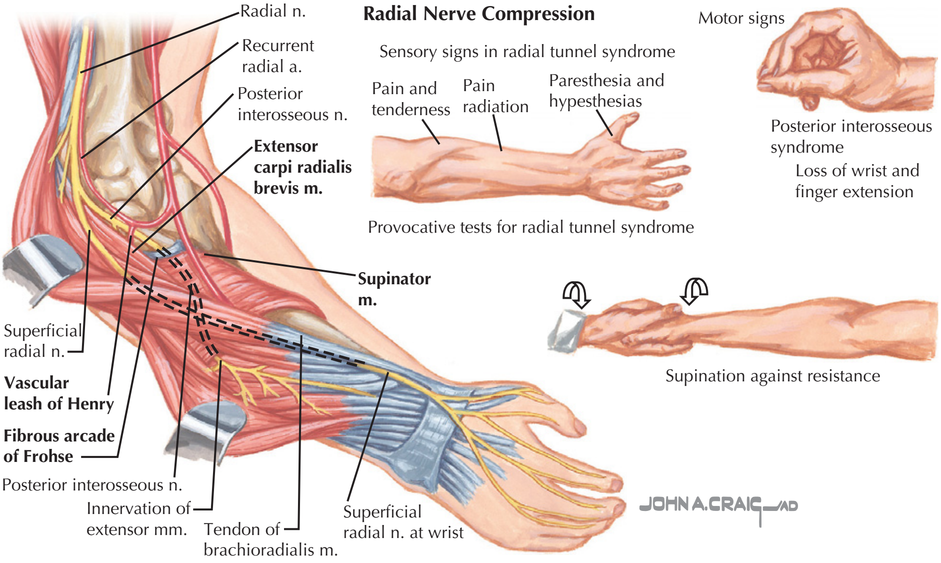
F. Netter M.D.

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
TRIANGULAR FIBROCARTILAGE COMPLEX (TFCC) TEAR			
• Can be traumatic (class 1) or degenerative (class 2) • Only periphery is vascular (i.e., peripheral tear can be repaired)	**Hx:** Ulnar wrist pain, +/− popping/grinding **PE:** TFC is TTP, + TFCC, grind, +/− piano key	**XR:** Usually normal; tears assoc. w/styloid base fx **MRA:** Study of choice for diagnosis of tears	1. Class 1: repair or debride tear (fix styloid fracture if needed) 2. Class 2: NSAIDs, splint; ulnar shortening procedure
de QUERVAIN'S TENOSYNOVITIS			
• Inflammation of first dorsal compartment (APL/EPB tendons) • Middle age women #1. • Assoc. w/tendon abnormality	**Hx:** Radial pain/swelling **PE:** Tenderness at 1st dorsal compartment, + Finkelstein's test	**XR:** Usually normal **MR:** No indication	1. Splint and NSAIDs 2. Corticosteroid injection into sheath 3. Surgical release
GANGLION CYST			
• Synovial fluid–filled cyst arising from a wrist joint • Most common mass in wrist • Dorsal wrist most common site (usually from SL joint)	**Hx:** Mass, +/− pain **PE:** Palpable, mobile mass, +/− tenderness, + transillumination	**XR:** Wrist series usually normal **MR:** Will show cyst well, needed only if diagnosis is uncertain	1. Observation if asymptomatic 2. Aspiration (recurrence 20%) 3. Excision (including stalk of cyst; recurrence <10%)


Median nerve
Supracondylar process
Ligament of Struthers
Medial epicondyle
Lacertus fibrosus
Pronator teres m.
Humeral head
Ulnar head
Flexor digitorum superficialis m. and arch
Flexor pollicis longus m.
Anterior interosseous n.
Carpal tunnel
Pronator syndrome
Flexion of middle finger against resistance
Compression by flexor digitorum superficialis muscle
Compression by pronator teres muscle
Pronation against resistance
Compression by lacertus fibrosus
Flexion of wrist against resistance
Anterior interosseous syndrome
Normal
Abnormal
Carpal tunnel syndrome
Incision site
Transverse carpal ligament
Median nerve
Decompressed carpal tunnel
Compressed median nerve
JOHN A.CRAIG_AD

Hand posture in anterior interosseous syndrome due to paresis of flexor digitorum profundus and flexor pollicis longus muscles

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
MEDIAN NERVE COMPRESSION			
Pronator Syndrome			
• Proximal median nerve compression • Sites: 1. Ligament of Struthers, 2. Pronator teres, 3. Lacertus fibrosis, 4. FDS aponeurosis/arch	**Hx:** Numbness, tingling, +/− weakness **PE:** Decreased palm sensation, + pronator or FDS sign	**XR:** Look for supracondylar process off humerus **EMG/NCS:** Can confirm dx (can also be normal)	1. Activity modification/ rest 2. Splinting, NSAIDs 3. Surgical decompression of all proximal compression sites
AIN Syndrome			
• Rare nerve compression • Same sites at pronator syndrome • Motor symptoms only	**Hx:** Weakness, +/− pain **PE:** Weak thumb (FPL) and IF (FDP) pinch	**XR:** Usually normal **EMG/NCS:** Will confirm diagnosis if unclear	1. Activity modification 2. Splinting, NSAIDs 3. Surgical decompression
Carpal Tunnel Syndrome			
• Compression in carpal tunnel • Most common neuropathy • Associated with metabolic diseases (thyroid, diabetes), pregnancy	**Hx:** Numbness, +/− pain **PE:** +/− thenar atrophy, + Durkin's, +/− Phalen's, & Tinel's tests	**XR:** Usually normal **EMG/NCS:** Will confirm diagnosis if unclear (incr. latency, decr. velocity)	1. Activity modification 2. Night splints, NSAIDs 3. Corticosteroid injection 4. Carpal tunnel release


Radial Nerve Compression
Radial n.
Recurrent radial a.
Posterior interosseous n.
Extensor carpi radialis brevis m.
Supinator m.
Superficial radial n.
Vascular leash of Henry
Fibrous arcade of Frohse
Posterior interosseous n.
Innervation of extensor mm.
Tendon of brachioradialis m.
Superficial radial n. at wrist
Sensory signs in radial tunnel syndrome
Pain and tenderness
Pain radiation
Paresthesia and hypesthesias
Provocative tests for radial tunnel syndrome
Motor signs
Posterior interosseous syndrome
Loss of wrist and finger extension
Supination against resistance
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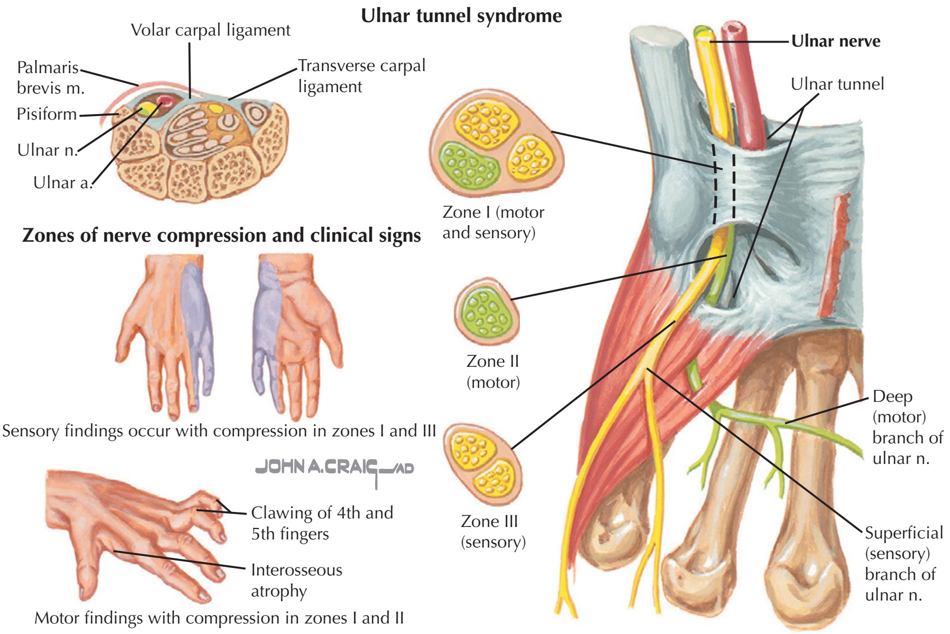
DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
RADIAL NERVE COMPRESSION			
PIN Syndrome			
• Compression in radial tunnel • Sites: 1. Fibrous bands, 2. Leash of Henry, 3. ECRB, 4. Arcade of Frohse (proximal supinator edge), 5. Distal edge of supinator	**Hx:** Hand & wrist weakness, +/– elbow pain **PE:** Weak thumb/finger ext., TTP at radial tunnel	**XR:** Look for radiocapitellar abnormality **MR:** Evaluate for masses **EMG/NCS:** Confirms diagnosis & localizes lesion	1. Activity modification 2. Splint, NSAIDs 3. Surgical decompression (complete release)
Radial Tunnel Syndrome			
• Compression in radial tunnel • Same sites as above • Pain only, no weakness	**Hx:** Lat. elbow pain **PE:** Radial tunnel TTP, no weakness	**XR:** Evaluate RC joint **MR:** Evaluate for masses **EMG/NCS:** Not useful	1. Activity modification 2. Splint, NSAIDs 3. Surgical decompression
Wartenberg's Syndrome			
• Compression of superficial radial nerve at wrist (b/w ERCL and BR tendons) • Sensory symptoms only	**Hx:** Numbness/pain **PE:** Decr. sensation IF/thumb. + Tinel's, sx w/pronation	**XR:** Usually normal **MR:** Usually not helpful **EMG/NCS:** May confirm diagnosis	1. Activity modification 2. Wrist splint, NSAIDs 3. Surgical decompression
ULNAR NERVE COMPRESSION			
Ulnar Tunnel (Guyon's Canal) Syndrome			
• Compression in Guyon's canal • Etiology: ganglion, hamate malunion, thrombotic a., muscle • Sensory (zone 3), motor (zone 2), or mixed (zone 1) symptoms	**Hx:** Numbness, weakness in hand **PE:** Decr. sensation, +/– atrophy, clawing, weakness	**XR:** Look for fracture **CT:** Evaluate for fx/malunion **MR:** Useful for masses **US:** Evaluate for thrombosis **EMG:** Confirm diagnosis	1. Activity modification 2. Splint, NSAIDs 3. Surgical decompression (address underlying cause of compression)


Ulnar tunnel syndrome

Volar carpal ligament
Palmaris brevis m.
Transverse carpal ligament
Pisiform
Ulnar n.
Ulnar a.
Zones of nerve compression and clinical signs
Sensory findings occur with compression in zones I and III
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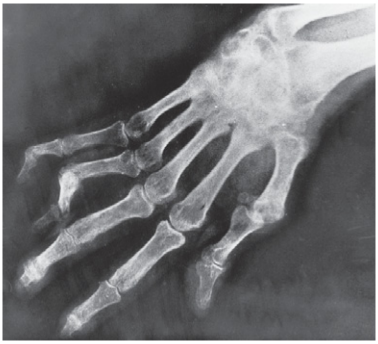
Clawing of 4th and 5th fingers
Interosseous atrophy
Motor findings with compression in zones I and II
Zone I (motor and sensory)
Zone II (motor)
Zone III (sensory)
Ulnar nerve
Ulnar tunnel
Deep (motor) branch of ulnar n.
Superficial (sensory) branch of ulnar n.

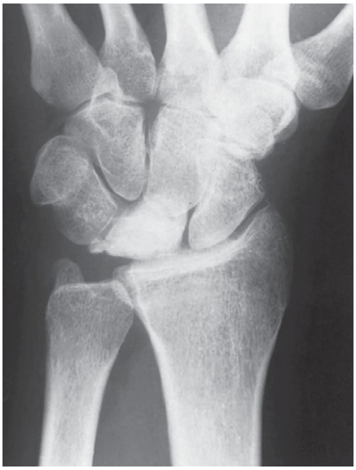
DESCRIPTION	EVALUATION	TREATMENT
CARPAL INSTABILITY		
Carpal Instability, Dissociative (CID)		
Instability within a carpal row; two main types: 1. Dorsal intercalated segment instability (**DISI**) ◦ Due to scapholunate (SL) ligament disruption or scaphoid fracture/nonunion ◦ Deformity: scaphoid flexes, lunate extends ◦ May lead to STT arthritis or SLAC wrist 2. Volar intercalated segment instability (**VISI**) ◦ Due to lunotriquetral ligament disrupted (also requires dorsal radiocarpal lig. injury)	**Hx:** Trauma, pain +/− popping **PE:** +/− decreased ROM, +/− snuffbox or SL/LT interval tenderness, + Watson test (DISI) or Regan test (VISI) **XR:** Wrist & clenched fist views ◦ DISI: SL gap >3mm, SL angle >70º, "ring sign" ◦ VISI: disrupted carpal arches **MRA:** Can confirm ligament inj.	**Acute/early treatment:** 1. Fx: ORIF of scaphoid 2. Ligament: SL or LT ligament repair or reconstruction with pin fixation 3. Capsulodesis **Chronic/late treatment:** 1. Limited fusion (e.g., STT fusion for DISI)
Carpal Instability, Nondissociative (CIND)		
- Instability between carpal rows - Midcarpal or radiocarpal variations - Associated with generalized hyperlaxity or trauma to ligaments (e.g., ulnar translation at RCJ) or to bones (e.g., distal radius fracture)	**Hx:** Fall/trauma or ligament hyperlaxity; popping/clunking **PE:** Tenderness, instability **XR:** Evaluate for fxs & static carpal translation **Fluoro:** Dynamic carpal transl.	1. Nonoperative: splint/cast (esp. midcarpal) 2. Arthrodesis (fusion) ◦ Midcarpal ◦ Radiocarpal
Carpal Instability, Combined (CIC)		
- Instability both within a row & between rows - Perilunate dislocation most common - Greater arc injury = transosseous injury - Lesser arc injury = ligamentous injury	**Hx:** Fall/trauma, pain **PE:** Tenderness, instability **XR:** Disruption of carpal arches, lunate abnormality (angle &/or position)	1. ORIF of bones with primary repair of ligaments 2. Late: arthrodesis

Rheumatoid Arthritis



Radiograph shows cartilage thinning at proximal interphalangeal joints, erosion of carpus and wrist joint, osteoporosis, and finger deformities

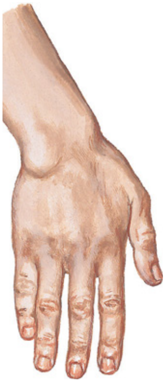
Kienböck's Disease



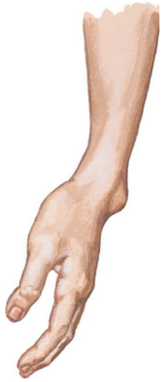
Radiograph of wrist shows characteristic sclerosis of lunate

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
DEGENERATIVE/ARTHRITIC CONDITIONS			
• Primary osteoarthritis in the wrist is uncommon. It is usually posttraumatic (distal radius/scaphoid fx or lig. injury).			
Scapholunate Advanced Collapse (SLAC)			
• Wrist arthritis due to posttraumatic scaphoid flexion deformity (SL ligament injury or scaphoid fracture [SNAC]) • Arthritis progresses over four stages (I-IV)	**Hx:** Prior trauma/fall (often untreated), pain **PE:** +/− decreased ROM with pain, tenderness to palpation	**XR:** 4 stages. DJD at: I. Rad. styloid & scaphoid II. Radioscaphoid joint III. Capitolunate joint IV. Capitate migration (radiolunate joint is spared)	I. Styloidectomy & STT fusion II. Proximal row carpectomy or scaphoidectomy & 4 corner (lun., tri., cap., ham.) fusion III. 4 corner fusion IV. Wrist arthrodesis (fusion)
Rheumatoid Arthritis			
• Inflammatory disorder attacks synovium and destroys joint • Radiocarpal (supination &, ulnar volar translation) & DRUJ (ulna subluxates dorsally) affected	**Hx:** Pain (esp. in AM), stiffness, deformity **PE:** Swelling, deformity (volar, ulnar translation of the carpus)	**XR:** Wrist series. Depends on severity. Mild degeneration to destruction of joint. **LABS:** RF, ANA, ESR	1. Medical management 2. Synovectomy 3. Tendon transfers 4. Wrist fusion or arthroplasty
Kienböck's Disease			
• Osteonecrosis of the lunate • Etiology: traumatic or repetitive microtrauma to lunate • 4 radiographic stages • Associated with ulnar negative variance of wrist	**Hx:** Pain, stiffness, and disability of wrist **PE:** Lunate/proximal row tenderness, decreased ROM, decreased grip strength	**XR:** Stage I: Normal x-ray; II: Lunate sclerosis IIIA: Lunate fragmented IIIB: IIIA + scaphoid flexed IV. DJD of adjacent joints **MR:** Needed to dx stage I	Stage: I: Immobilization I-IIIA: Radial shortening IIIB: STT fusion or proximal row carpectomy (PRC) IV: Wrist fusion or PRC

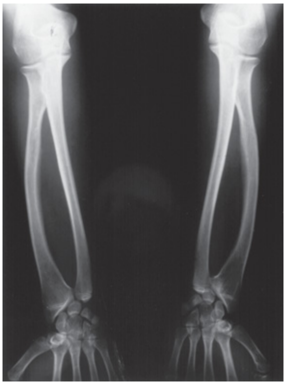
Madelung's Deformity



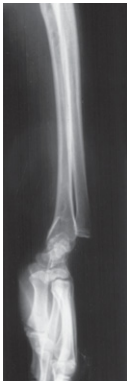
Dorsal view of hand reveals prominence of ulnar heads



Prominence of ulnar head, palmar deviation of hand, and bowing of forearm clearly seen on radial view

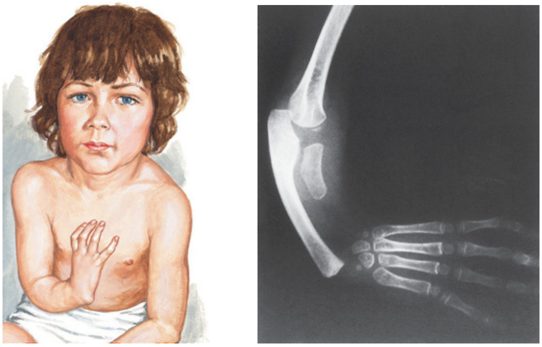


Radiograph shows ulnar inclination of articular surfaces of distal radius, wedging of carpal bones into resulting space, and bowing of radius

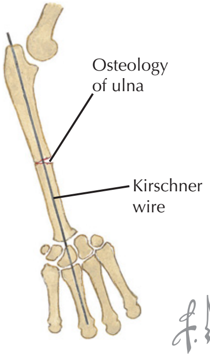


Lateral radiograph demonstrates dorsal prominence of ulnar head with palmar deviation of carpal bones

Radial Club Hand



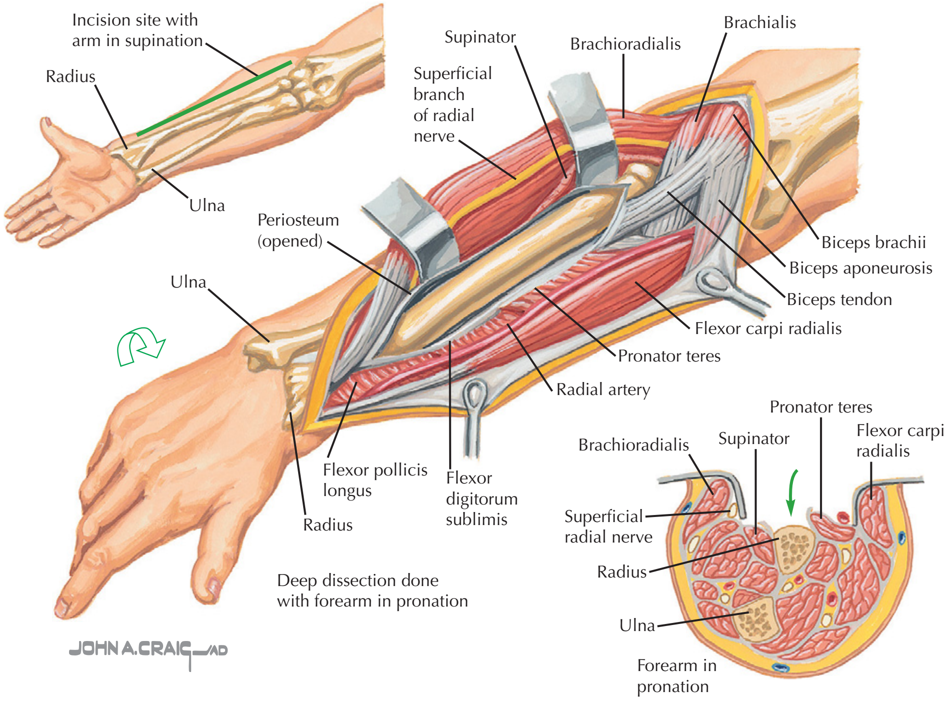
Short, bowed forearm with marked radial deviation of hand. Thumb absent. Radiograph shows partial deficit of radial ray (vestige of radius present). Scaphoid, trapezium, and metacarpal and phlanges of thumb absent.



Centralization procedure

DESCRIPTION	EVALUATION	TREATMENT
MADELUNG'S DEFORMITY		
• Deformity of the distal radius • Volar ulnar physis disrupted causes increased volar tilt & radial inclination • Ages 6-12; females>males	**Hx:** Pain in wrists & deformity **PE:** Deformity & prominent ulna head **XR:** Distal radius deformity (incr. tilt & inclination) & dorsal ulna subluxation	Asymptomatic: observation and/or activity modification Symptomatic: radial osteotomy +/− ulna recession
RADIAL CLUB HAND (RADIAL HEMIMELIA)		
• Failure of formation (partial or complete: stages I-IV) of the radius • Associated with syndromes (TAR, VATER)	**Hx/PE:** Bowing of forearm, radial deviation of hand **XR:** Radius short or absent, bowed ulna	1. Elbow ROM (no surgery if stiff) 2. Hand centralization (age 1)

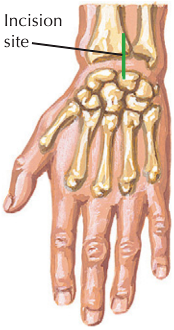
Posterior Approach to Forearm

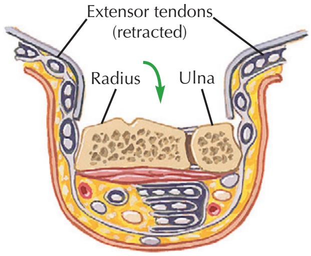

Incision site with arm in supination
Radius
Ulna
Supinator
Superficial branch of radial nerve
Brachioradialis
Brachialis
Periosteum (opened)
Biceps brachii
Biceps aponeurosis
Biceps tendon
Flexor carpi radialis
Pronator teres
Radial artery
Ulna
Flexor pollicis longus
Flexor digitorum sublimis
Radius
Pronator teres
Brachioradialis
Supinator
Flexor carpi radialis
Superficial radial nerve
Radius
Ulna
Forearm in pronation
JOHN A.CRAIG—AD

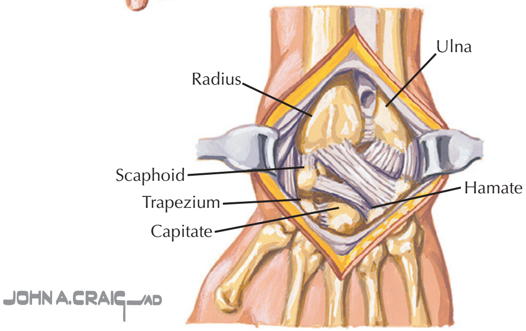
Deep dissection done with forearm in pronation

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
FOREARM: ANTERIOR APPROACH (HENRY)			
• ORIF of fractures • Osteotomy • Biopsy & bone tumors	**Proximal** ∘ Brachioradialis (radial) ∘ Pronator teres (median) **Distal** ∘ Brachioradialis (radial) ∘ FCR (median)	• Radial artery • Superficial radial nerve • Posterior interosseous nerve (PIN)	• Most commonly only a portion of the incision is needed/used • Proximally, must ligate the radial recurrent artery • Distally, must detach pronator quadratus to get to distal radius
WRIST: DORSAL APPROACH			
• ORIF of fractures • Wrist fusion or carpectomy • Tendon repair	• No internervous plane (muscles all innervated by radial nerve [PIN]) • 4th dorsal compartment is opened & tendons are retracted	• Superficial radial nerve • Radial artery	• If needed, a compartment other than the 4th can be opened • The capsular sensory branch of the PIN is in the 4th compartment
WRIST: VOLAR APPROACH			
• ORIF (e.g., distal radius, scaphoid) • Carpal tunnel release • Tendon repair	**Proximal** (same as Henry) ∘ Brachioradialis (radial) ∘ FCR (median) **Distal** (over wrist & palm) ∘ None	• Median nerve ∘ Palmar cutaneous br. ∘ Motor recurrent branch • Superficial palmar arch	• Incise transverse carpal ligament to access volar wrist capsule/bones • Must detach pronator quadratus to expose distal radius

Dorsal Approach to Wrist Joint


Incision
site


Extensor tendons
(retracted)
Radius
Ulna


Ulna
Radius
Scaphoid
Trapezium
Capitate
Hamate
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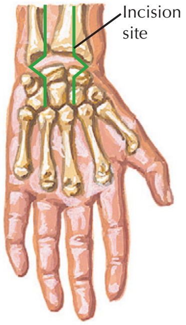
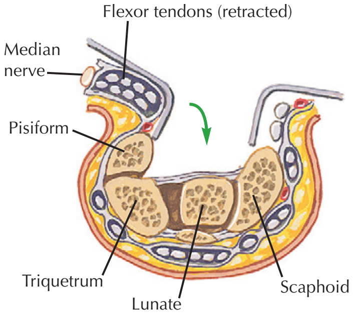
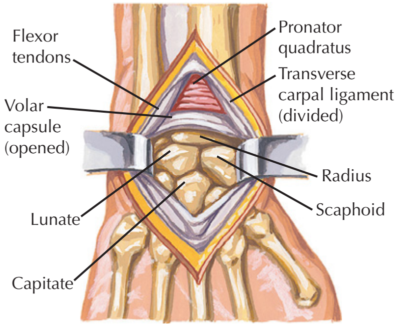
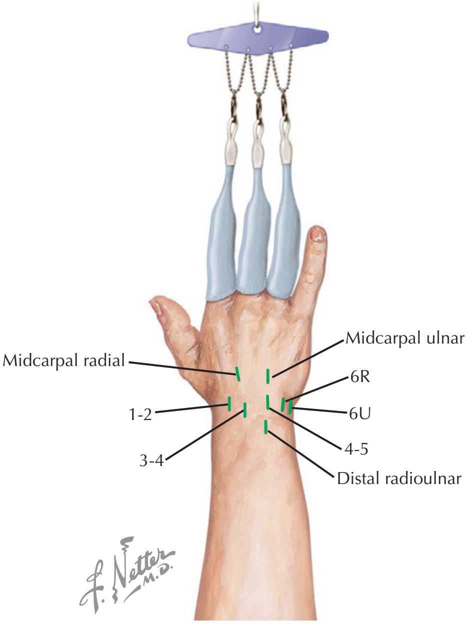
Volar Approach to Wrist Joint


Incision
site


Flexor tendons (retracted)
Median
nerve
Pisiform
Triquetrum
Lunate
Scaphoid


Flexor
tendons
Volar
capsule
(opened)
Lunate
Capitate
Pronator
quadratus
Transverse
carpal ligament
(divided)
Radius
Scaphoid



PORTAL	LOCATION	DANGERS	COMMENT
WRIST ARTHROSCOPY PORTALS			
• Uses: Diagnostic, TFCC **tears**, synovectomy, assist in fracture fixation, loose body removal, chondral lesions • Portals are named for relation to the dorsal extensor wrist compartments (*R & U* indicate radial or ulnar side of tendon).			
1-2	Between APL & ECRL tendons. Distal to radial styloid	1. Deep branch of radial art. 2. Superficial radial n. brs. 3. Lat. antebrachial cut. brs.	• Use is limited b/c of close proximity to & risk of neurovascular injury • Shows distal scaphoid & radial styloid
3-4	Between EPL & EDC tendons, 1cm distal to Lister's tubercle	None (PIN capsular br. in 4th comp)	• The "workhorse" portal of arthroscopy • Shows SL interosseous lig., ligament of Testut (RSL), distal radius fossae
4-5	Between EDC & EDQ tendons	None	• Shows radial TFCC attachment, LT interosseous ligament
6R	Radial side of ECU tendon (b/w EDQ & ECU)	Dorsal cutaneous br. ulnar n.	• Shows ulnar insertion of TFCC, UT, & UL ligaments, prestyloid recess
6U	Ulnar side of ECU tendon	Dorsal cutaneous br. ulnar n.	• Similar to 6R. Used less due to risk of nerve injury. Can be used for outflow.
Midcarpal radial	1cm distal to 3-4 portal, along radial border of 3rd MC	None	• Distal scaphoid, proximal capitate, SL ligament, STT articulation
Midcarpal ulnar	1cm distal to 4-5 portal, in line with 4th MC	None	• Lunotriquetral joint, LT ligament, triquetrohamate articulation
Other portals: Midcarpal: STT and triquetrohamate. Distal radioulnar: proximal and distal to ulnar head.			
FASCIOTOMIES			
See page 169.			

CHAPTER 6

Hand

Topographic Anatomy 184

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Arteries 212

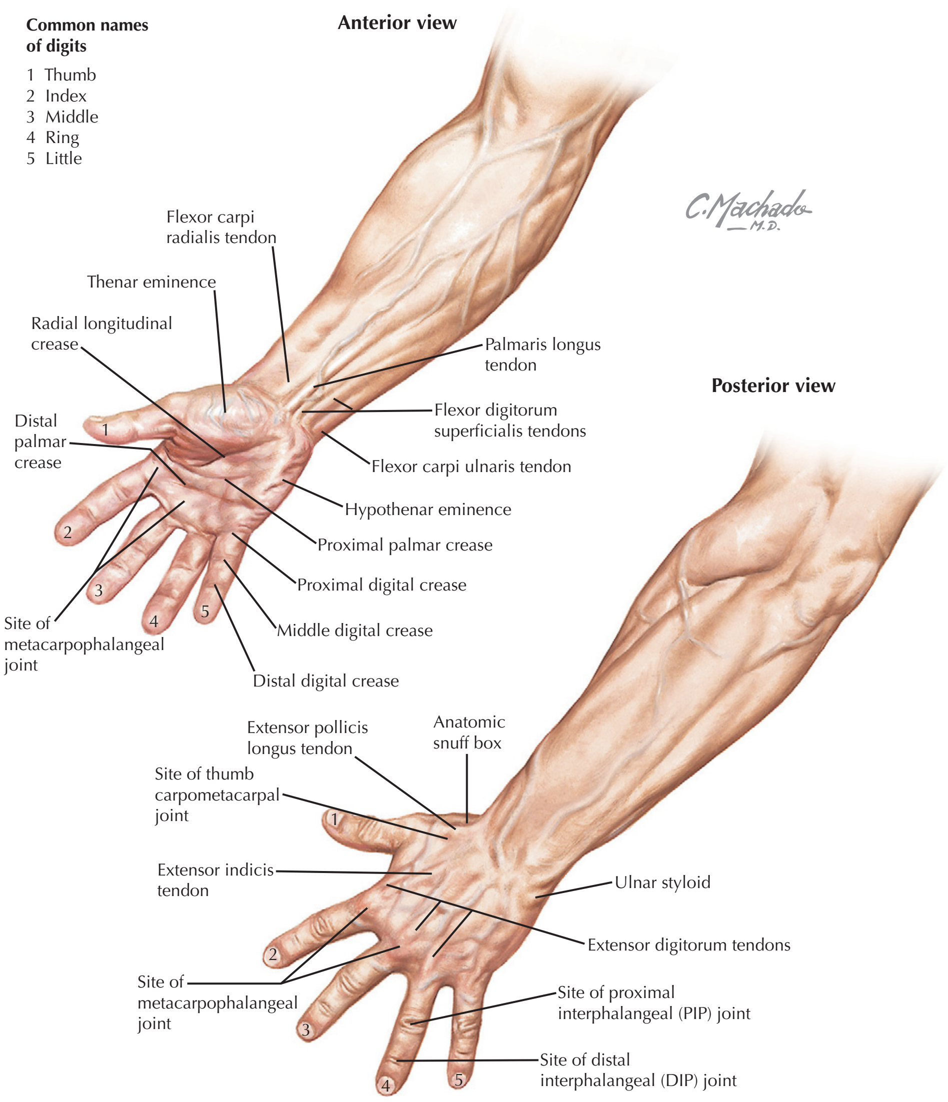
Disorders 213

Pediatric Disorders 216

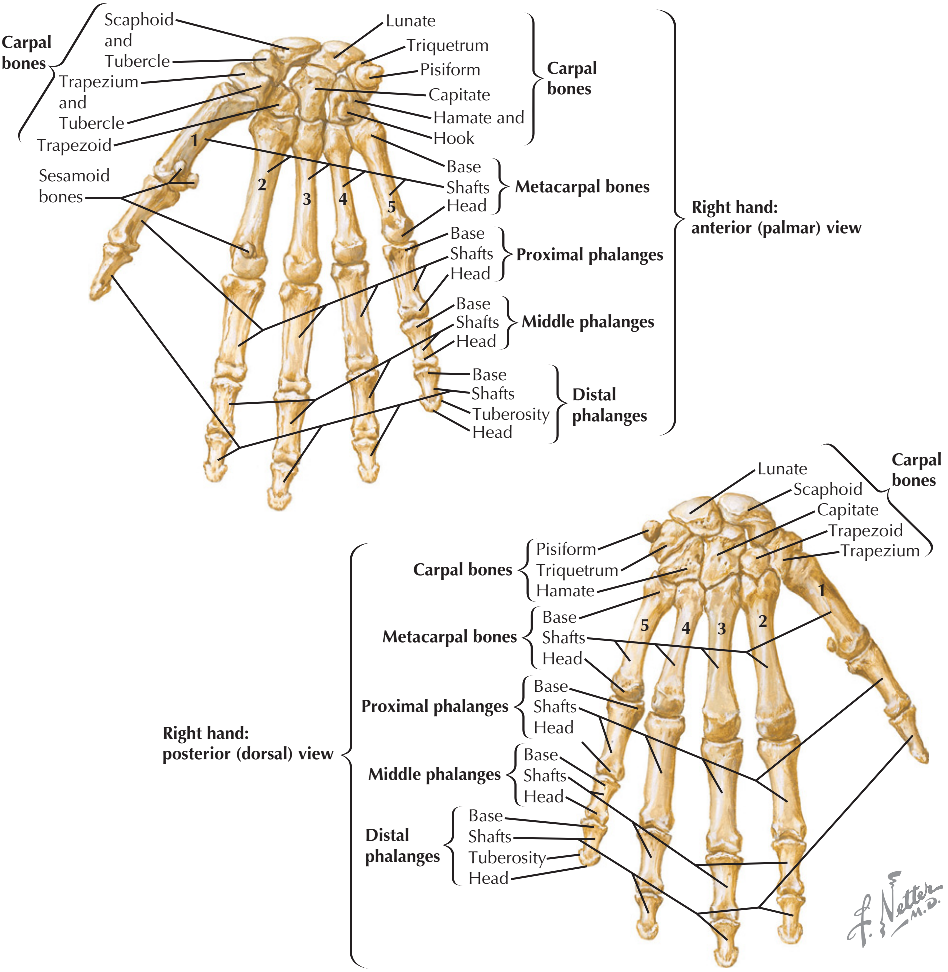
Surgical Approaches 218

Common names of digits

1 Thumb
2 Index
3 Middle
4 Ring
5 Little

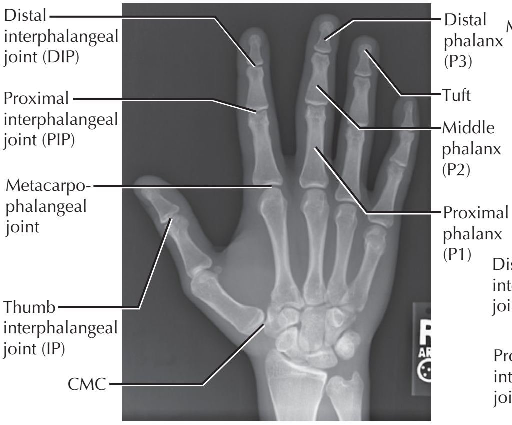

Anterior view
Flexor carpi radialis tendon
Thenar eminence
Radial longitudinal crease
Distal palmar crease
Palmaris longus tendon
Flexor digitorum superficialis tendons
Flexor carpi ulnaris tendon
Hypothenar eminence
Proximal palmar crease
Proximal digital crease
Middle digital crease
Distal digital crease
Site of metacarpophalangeal joint
1
2
3
4
5
Posterior view
Extensor pollicis longus tendon
Anatomic snuff box
Site of thumb carpometacarpal joint
Extensor indicis tendon
Ulnar styloid
Extensor digitorum tendons
Site of metacarpophalangeal joint
Site of proximal interphalangeal (PIP) joint
Site of distal interphalangeal (DIP) joint
1
2
3
4
5
C. Machado M.D.

STRUCTURE	CLINICAL APPLICATION
Palmaris longus tendon	Not present in all people. Can be used for tendon grafts.
Anatomic snuffbox	Site of scaphoid. Tenderness can indicate a scaphoid fracture.
Thumb carpometacarpal joint	Common site of arthritis and source of radial hand pain.
Thenar eminence	Atrophy can indicate median nerve compression (e.g., carpal tunnel syndrome).
Hypothenar eminence	Atrophy can indicate ulnar nerve compression (e.g., ulnar or cubital tunnel syndrome).
Proximal palmar crease	Approximate location of the superficial palmar arch of the palm.
Distal palmar crease	Site of metacarpophalangeal joints on volar side of hand.

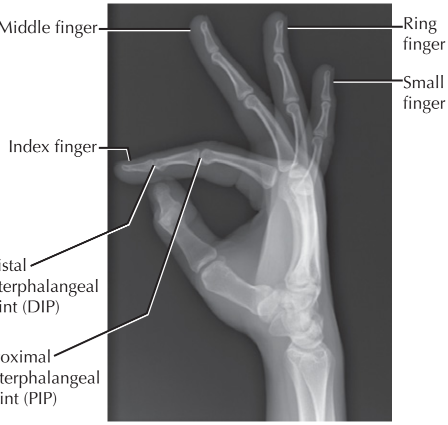

Carpal bones
Scaphoid and Tubercle
Trapezium and Tubercle
Trapezoid
Sesamoid bones
Lunate
Triquetrum
Pisiform
Capitate
Hamate and Hook
Carpal bones
1
2
3
4
5
Base
Shafts
Head
Metacarpal bones
Base
Shafts
Head
Proximal phalanges
Base
Shafts
Head
Middle phalanges
Base
Shafts
Tuberosity
Head
Distal phalanges
Right hand: anterior (palmar) view
Lunate
Scaphoid
Capitate
Trapezoid
Trapezium
Carpal bones
Pisiform
Triquetrum
Hamate
Carpal bones
Base
Shafts
Head
Metacarpal bones
5
4
3
2
1
Base
Shafts
Head
Proximal phalanges
Base
Shafts
Head
Middle phalanges
Base
Shafts
Tuberosity
Head
Distal phalanges
Right hand: posterior (dorsal) view
F. Netter M.D.

CHARACTERISTICS	OSSIFY		FUSE	COMMENT
METACARPALS				
• Triangular in cross section: gives 2 volar muscular attachment sites	**Primary:** body	9wk (fetal)	18yr	• Named I-V (thumb to small finger)
• Thumb MC has saddle-shaped base: increases it mobility	**Secondary** epiphysis	2yr	18yr	• Only one physis per bone in the head; base in thumb MC
PHALANGES				
• Volar surface is almost flat	**Primary:** body	8wk (fetal)	14-18yr	• 3 in each digit except thumb (two)
• Tubercles and ridges are sites for attachment	**Secondary** epiphysis	2-3yr	14-18yr	• Only one physis per bone; it is in the base
• Nomenclature for digits: thumb, index finger (IF), middle finger (MF), ring finger (RF), small/little finger (SF or LF), proximal phalanx (P1), middle phalanx (P2), distal phalanx (P3)				

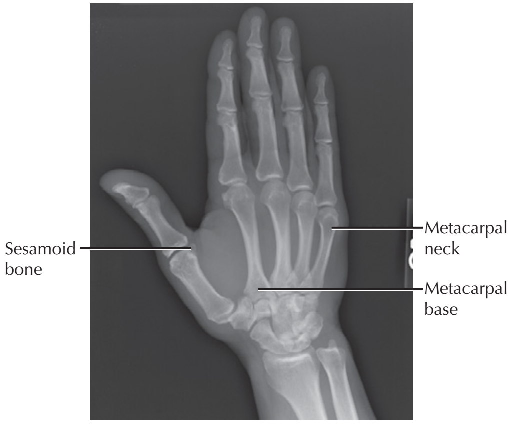
X-ray, hand


Distal interphalangeal joint (DIP)
Proximal interphalangeal joint (PIP)
Metacarpo-phalangeal joint
Thumb interphalangeal joint (IP)
CMC
Distal phalanx (P3)
Tuft
Middle phalanx (P2)
Proximal phalanx (P1)

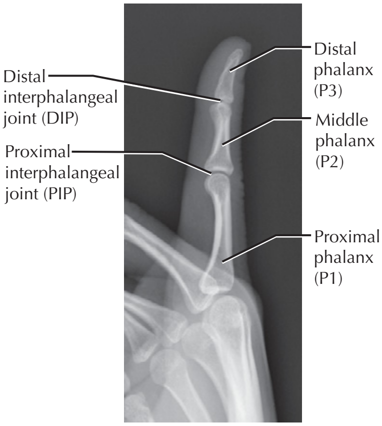
Lateral x-ray, finger


Middle finger
Index finger
Distal interphalangeal joint (DIP)
Proximal interphalangeal joint (PIP)
Ring finger
Small finger

X-ray, hand

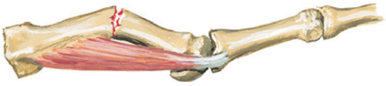

Sesamoid bone
Metacarpal neck
Metacarpal base

X-ray, finger

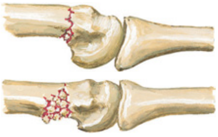

Distal interphalangeal joint (DIP)
Proximal interphalangeal joint (PIP)
Distal phalanx (P3)
Middle phalanx (P2)
Proximal phalanx (P1)

RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
AP (anteroposterior)	Palm down on plate, beam perpendicular to plate	Metacarpals, phalanges, CMC, MCP, and IP joints	Hand & finger fractures, hand joint dislocations and DJD
Lateral	Ulnar wrist and hand on plate, stagger finger flexion	Alignment of bones, joints	Same as above
Oblique	Lateral with 40° rotation	Alignment and position of bones	Same as above
Thumb stress view	Abduct thumb at 0° & 30° of flexion, beam at MCPJ	Thumb MCPJ under stress	Evaluate ulnar collateral ligament integrity (gamekeeper's thumb)
OTHER STUDIES			
CT	Axial, coronal, and sagittal	Articular congruity, bone healing, bone alignment	Fractures (esp. scaphoid, hook of hamate), nonunions
MRI	Sequence protocols vary	Soft tissues (ligaments, tendons), bones	Occult fractures (e.g., scaphoid), ligament/tendon injuries
Bone scan		All bones evaluated	Infection, stress fxs, tumors

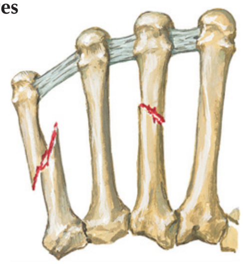
Metacarpal Fractures



Transverse fractures of metacarpal shaft usually angulated dorsally by pull of interosseous muscles

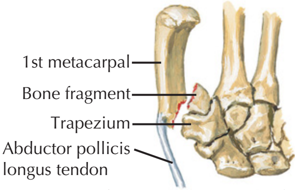


In fractures of metacarpal neck, volar cortex often comminuted, resulting in marked instability after reduction, which often necessitates pinning

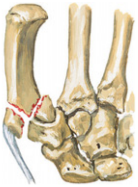


Oblique fractures tend to shorten and rotate metacarpal, particularly in index and little fingers because metacarpals of middle and ring fingers are stabilized by deep transverse metacarpal ligaments

Fracture of Base of Metacarpals of Thumb

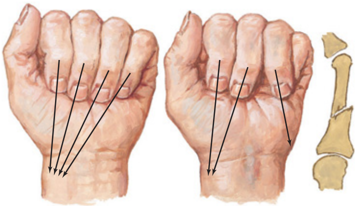


Type I (Bennett fracture). Intraarticular fracture with proximal and radial dislocation of 1st metacarpal. Triangular bone fragment sheared off



Type II (Rolando fracture). Intraarticular fracture with Y-shaped configuration

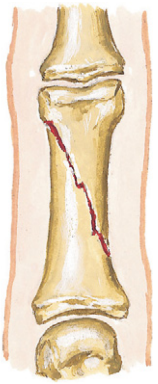
Fracture of Proximal Phalanx



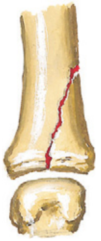
Reduction of fractures of phalanges or metacarpals requires correct rotational as well as longitudinal alignment. In normal hand, tips of flexed fingers point toward tuberosity of scaphoid, as in hand at left.

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
METACARPAL FRACTURES			
• Common in adults, usually a fall or punching mechanism • 5th MC most common (boxer fx) • Thumb MC base fractures: displaced, intraarticular fractures problematic ◦ Bennett's fx: APL deforms fx ◦ Rolando's fx: can lead to DJD • 4th & 5th MCs can tolerate some angulation, 2nd & 3rd cannot	**Hx:** Trauma, pain, swelling, +/– deformity **PE:** Swelling, tenderness. Check for rotational deformity. Check neurovascular integrity. **XR:** Hand. Evaluate for angulation & shortening **CT:** Useful to evaluate for nonunion of fracture	By location: • Head • Neck (most common) • Shaft (transverse, spiral) • Base ◦ Thumb MC ◦ Bennett: volar lip fx ◦ Rolando: comminuted ◦ Small finger MC: "Baby Bennett"	• Nondisplaced: cast • Displaced: reduce ◦ Stable: cast ◦ Unstable: CR-PCP vs. ORIF ◦ Shortened: ORIF • Intraarticular ◦ Head: ORIF ◦ Thumb base: ◦ Bennett: CR-PCP ◦ Rolando: ORIF
COMPLICATIONS: Nonunion/malunion, grip strength deficiency, posttraumatic osteoarthritis (esp. Rolando fractures)			

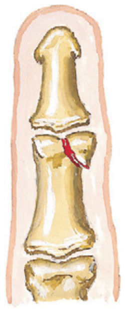
Phalangeal Fractures



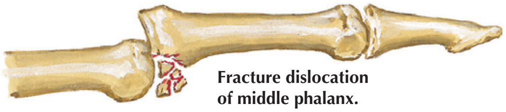
Extraarticular oblique shaft (diaphysis) **fracture.**



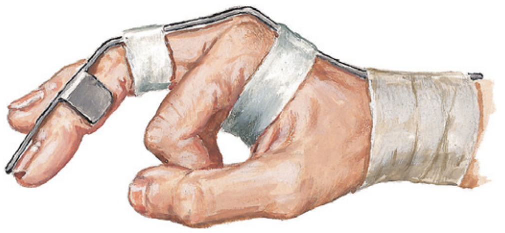
Intraarticular phalangeal base **fracture.** Intraarticular fractures of phalanx that are nondisplaced and stable may be treated with buddy taping, careful observation, and early active exercise.



Intraarticular condyle fractures.

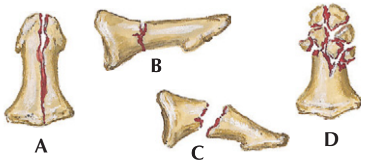


Fracture dislocation of middle phalanx.



Extension block splint useful for fracture dislocation of proximal

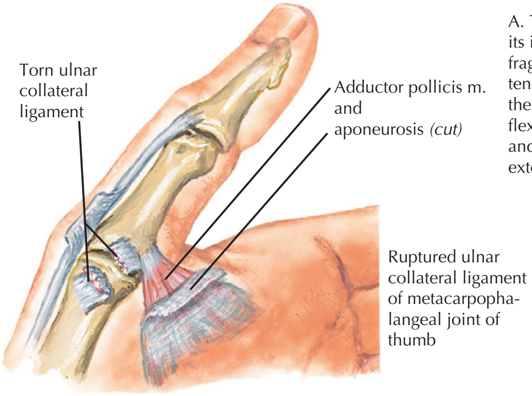
Fractures of distal phalanx



Types of fractures.
A. Longitudinal
B. Nondisplaced transverse
C. Angulated transverse
D. Comminuted

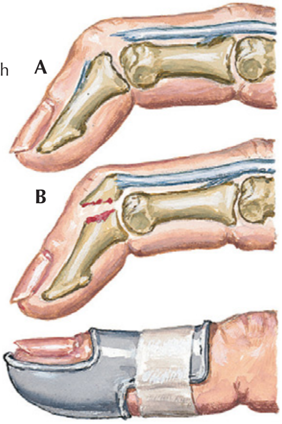
DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
PHALANGEAL FRACTURES			
• Common injury • Mechanism: jamming, crush, or twisting • Distal phalanx most common • Stiffness is common problem; early motion and occupational therapy needed for best results • Intraarticular fractures can lead to early osteoarthritis • Nail bed injury common w/ tuft (distal phalanx) fx	**Hx:** Trauma, pain, swelling, +/– deformity **PE:** Swelling, tenderness. Check for rotational deformity. Check neurovascular integrity. **XR:** Hand. Evaluate for angulation & shortening **CT:** Useful to evaluate for nonunion of fracture	Description: • Intra- vs extraarticular • Displaced/ nondisplaced • Transverse, spiral, oblique Location: • Condyle • Neck • Shaft/diaphysis • Base • Tuft	• Extraarticular: ◦ Stable: buddy tape/ splint ◦ Unstable: CR-PCP vs ORIF • Intraarticular: ORIF • Middle phalanx volar base fx: ◦ Stable: extension block splint ◦ Unstable: ORIF • Tuft fx: irrigate wound, repair nail bed as needed, splint fx/digit
COMPLICATIONS: Stiffness/loss of range of motion (esp. intraarticular fractures), nonunion/malunion, osteoarthritis			

Gamekeeper's thumb


Torn ulnar collateral ligament
Adductor pollicis m. and aponeurosis *(cut)*
Ruptured ulnar collateral ligament of metacarpophalangeal joint of thumb

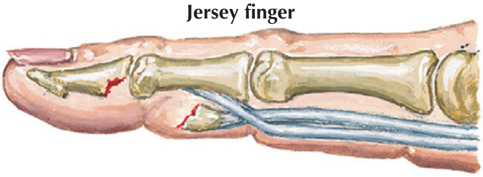
Mallet finger

A. Tendon torn from its insertion. B. Bone fragment avulsed with tendon. In A and B there is a 40°- 45° flexion deformity and loss of active extension



Splinted Mallet Finger

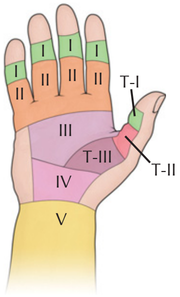
Jersey finger



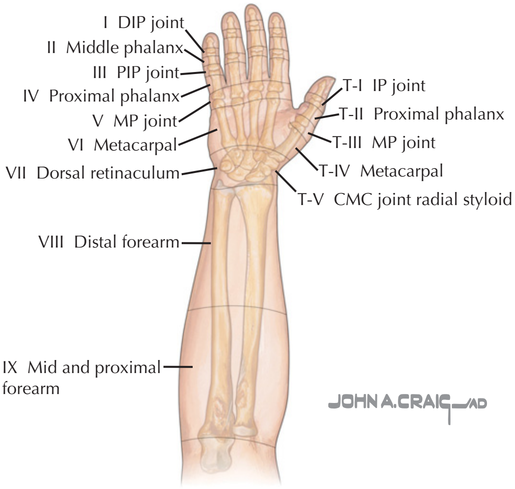
Flexor digitorum profundus tendon may be torn directly from distal phalanx or may avulse small or large bone fragment.

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
MALLET FINGER—EXTENSOR DIGITORUM AVULSION			
• Rupture of extensor tendon from distal phalanx • Soft tissue or bony form • Mech: jamming finger	**Hx:** "Jammed" finger; pain, DIPJ deformity **PE:** Extensor lag at DIPJ; inability to actively extend DIPJ	**XR:** Hand series. Look for bony avulsion (EDC) fx from dorsal base of P3 in bony form of injury	1. DIPJ extension splint, 6wk for most injuries 2. Bony mallet with DIPJ subluxation: consider PCP vs ORIF
JERSEY FINGER—FLEXOR DIGITORUM PROFUNDUS AVULSION			
• FDP tendon rupture from P3 • Mech: forced extension against a flexed finger • Tendon retracts variably	**Hx:** Forced DIPJ extension, injury; pain **PE:** Inability to flex DIPJ (−profundus test)	**XR:** Hand series. Look for avulsion fracture from volar base of P3. May be retracted to finger/palm.	Leddy classification: Type: • 1: to palm. Early repair • 2: to PIPJ. Repair <6wk • 3: bony to A4: ORIF
GAMEKEEPER'S THUMB			
• Thumb MCP joint proper ulnar collateral ligament injury • Mech: forced radial deviation • Often a ski pole injury	**Hx:** Pain, decreased grip **PE:** Pain & laxity of MCPJ at 30° of flexion, +/− palpable mass (Stenor lesion)	**XR:** Hand; r/o avulsion fx **Stress Fluoro:** Can compare side to side asym. **MR:** If diagnosis is unclear	• Incomplete tear (sprain) or no Stenor lesion: splint 4-6wk • Complete tear or Stenor lesion: primary repair
• **Stenor lesion:** when adductor aponeurosis falls under torn ulnar collateral ligament, producing a palpable mass/bump • Stress testing of the thumb MCP in extension tests the accessory collateral ligament and volar plate integrity			

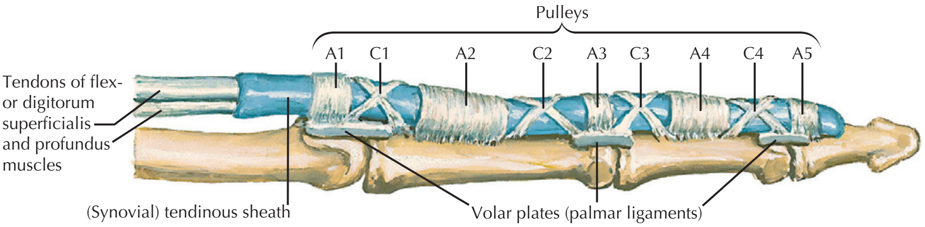
Flexor zones of hand

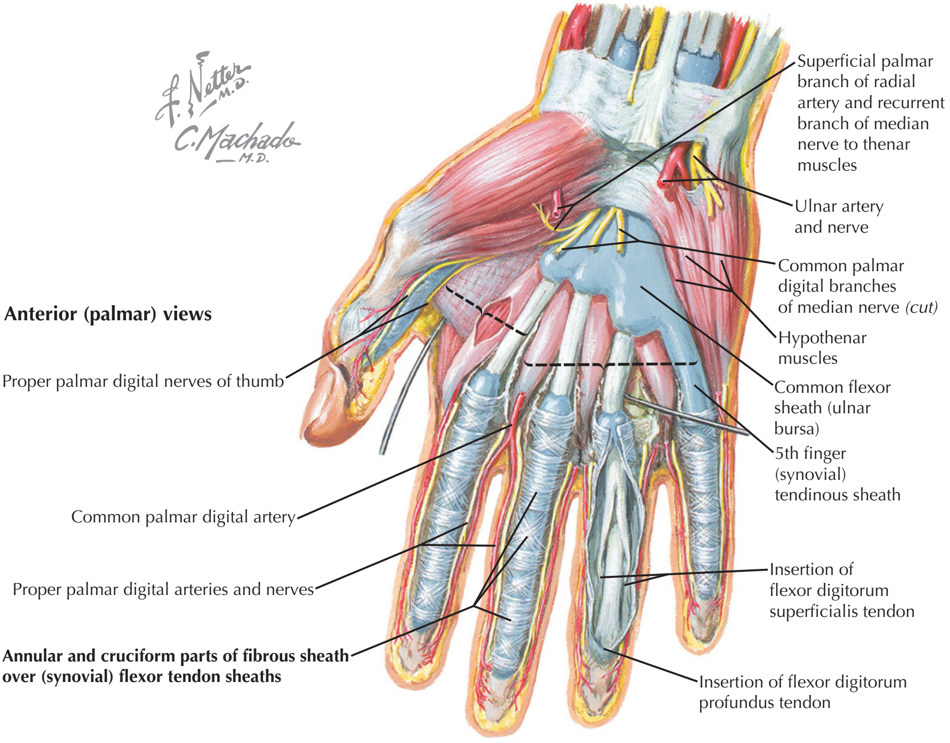

I
I
I
I
II
II
II
II
II
T-I
III
T-III
T-II
IV
V

Extensor zones of hand

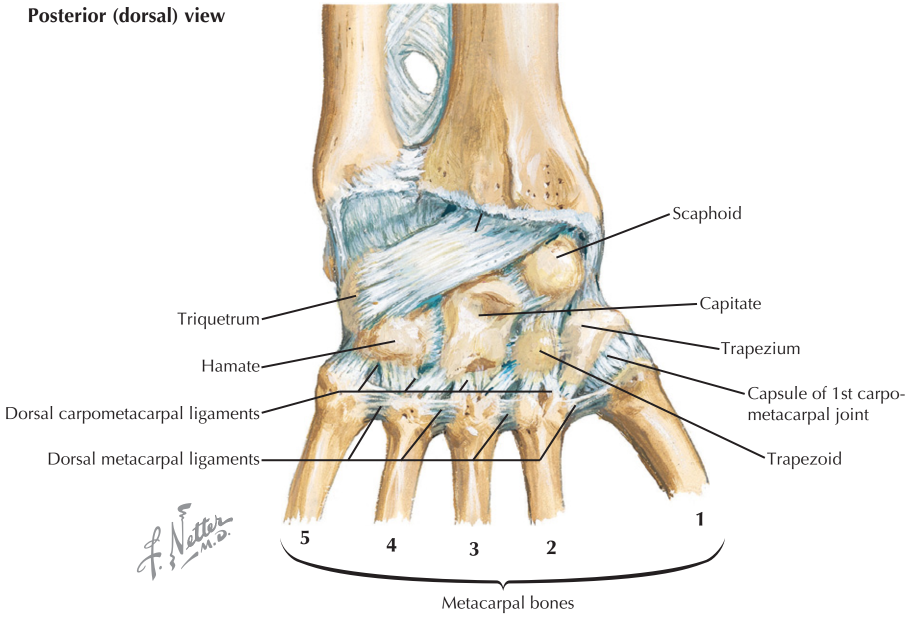

I DIP joint
II Middle phalanx
III PIP joint
IV Proximal phalanx
V MP joint
VI Metacarpal
VII Dorsal retinaculum
VIII Distal forearm
IX Mid and proximal forearm
T-I IP joint
T-II Proximal phalanx
T-III MP joint
T-IV Metacarpal
T-V CMC joint radial styloid
JOHN A.CRAIG—MD

ZONE	BOUNDARIES	COMMENT
FLEXOR TENDON ZONES		
I	Distal to FDS insertion	Single tendon (FDP) injury. Primary repair. DIPJ contracture results if tendon shortened >1cm. Quadriga effect can also result
II	Finger flexor retinaculum	"No man's land." Both tendons(FDS, FDP) require early repair (within 7 days) and mobilization. Lacerations may be at different locations on each tendon and away from skin laceration. Preserve A2 & A4 pulleys during repair
III	Palm	Primary repair. Arterial arch & median nerve injuries common.
IV	Carpal tunnel	Must release & repair the transverse carpal ligament during tendon repair.
V	Wrist & forearm	Primary repair (+ any neurovascular injury). Results are usually favorable.
Thumb I	Distal to FPL insertion	Primary tendon repair. Rerupture rate is high.
Thumb II	Thumb flexor retinaculum	Primary tendon repair. Preserve either A1 or oblique pulley.
Thumb III	Thenar eminence	Do not operate in this zone. Recurrent motor branch is at risk of injury.
EXTENSOR TENDON ZONES		
I	DIP joint	"Mallet finger." Splint in extension for 6 wk continuously.
II	Middle phalanx	Complete lacerations: primary repair and extension splint.
III	PIP joint	Central slip injury. Splint in extension for 6 wk. If triangular ligament is also disrupted, lateral bands migrate volarly, resulting in "boutonniere finger"
IV	Proximal phalanx	Primary repair of tendon (and lateral bands if needed), then extension splint
V	MCP joint	Often from "fight bite." Repair tendon and sagittal bands as needed.
VI	Metacarpal	Primary repair and early mobilization/dynamic splinting.
VII	Wrist	Retinaculum likely injured. Primary tendon repair, early mobilization.
VIII	Distal forearm	At musculotendinous jxn. Primary repair of tendinous tissue & immobilize
IX	Proximal forearm	Often muscle injury. Neurovascular injury high. Repair muscle & immobilize.

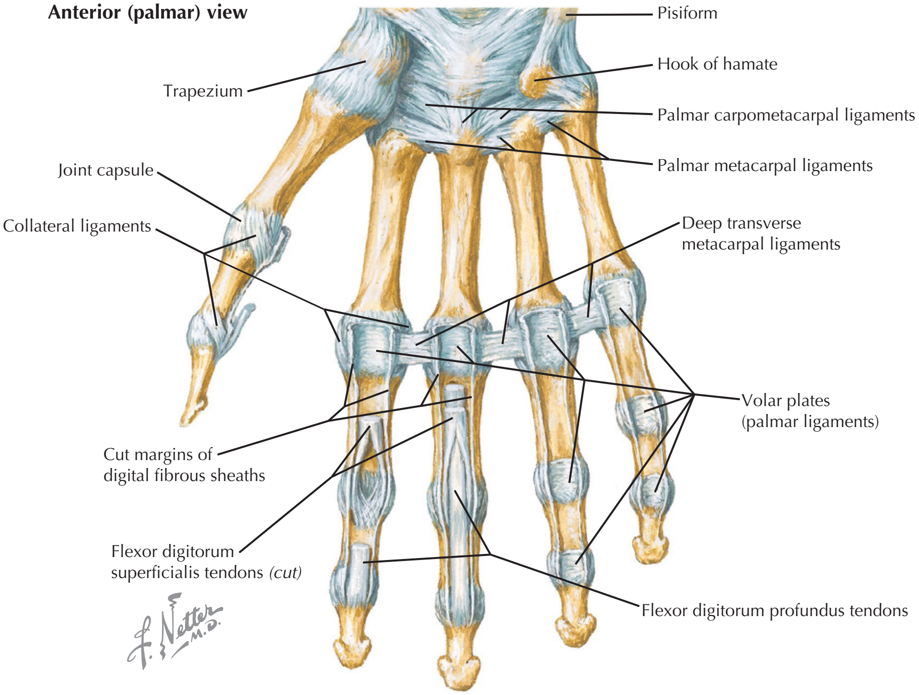

Pulleys
A1
C1
A2
C2
A3
C3
A4
C4
A5
Tendons of flexor digitorum superficialis and profundus muscles
(Synovial) tendinous sheath
Volar plates (palmar ligaments)


Anterior (palmar) views
Superficial palmar branch of radial artery and recurrent branch of median nerve to thenar muscles
Ulnar artery and nerve
Common palmar digital branches of median nerve *(cut)*
Hypothenar muscles
Common flexor sheath (ulnar bursa)
5th finger (synovial) tendinous sheath
Insertion of flexor digitorum superficialis tendon
Insertion of flexor digitorum profundus tendon
Proper palmar digital nerves of thumb
Common palmar digital artery
Proper palmar digital arteries and nerves
Annular and cruciform parts of fibrous sheath over (synovial) flexor tendon sheaths

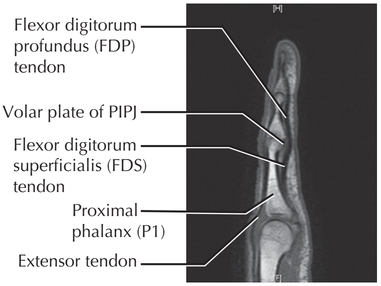
STRUCTURE	DESCRIPTION	COMMENT
FLEXOR TENDON SHEATH		
Flexor tendon sheath	Fibroosseous tunnel lined with tenosynovium Protects, lubricates, and nourishes the tendon	Site of possible infection; check for Kanavel signs (see Disorders table)
Pulleys	Thickenings of sheath to stabilize tendons 5 annular (A1[MCPJ], A3[PIPJ], A5[DIPJ] over joints; A2, A4 over phalanges) 3 or 4 cruciate pulleys	A2 & A4 (over P1 & P2) most important; must be intact to prevent “bowstringing” of tendons Tight A1 can cause a trigger finger A3 covers PIPJ volar plate: incise to access
Vincula	Within sheath, give vascular supply to tendons: 2 vincula (longa and brevia)	Vincula torn in type 1 FDP rupture (dysvascular), preserved in types 2 & 3 rupture
Volar plate (palmar ligament)	Thickening of volar capsule of interphalangeal joints	FDS & FDP tendons insert here to flex the PIP & DIP joints, respectively. Prevent hyperextension.

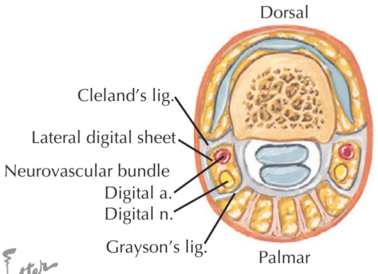

Posterior (dorsal) view
Scaphoid
Capitate
Trapezium
Capsule of 1st carpometacarpal joint
Trapezoid
Triquetrum
Hamate
Dorsal carpometacarpal ligaments
Dorsal metacarpal ligaments
F. Netter M.D.
5
4
3
2
1
Metacarpal bones

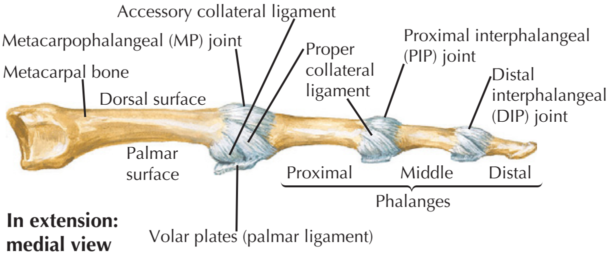
LIGAMENT	ATTACHMENTS	COMMENTS
CARPOMETACARPAL		
Thumb		
• Saddle joint. Highly mobile, has both inherent bony and ligamentous stability. Prone to develop osteoarthritis • Primary movements: flexion, extension, adduction, abduction • Complex (combined) movements: opposition, retropulsion, palmar abduction, radial abduction/adduction		
Capsule	Base of metacarpal to trapezium	Surrounds joint and is a secondary stabilizer
Anterior (volar) **oblique**	Ulnar side of 1st metacarpal base to tubercle of trapezium	"Beak" ligament. Holds fragment in Bennett's fx. Primary restraint to subluxation. Injury can lead to osteoarthritis.
Dorsal radial	Dorsal trapezium to dorsal MC base	Strongest. Dorsal and radial support. Torn in dorsal dislocation.
1st intermetacarpal	Ulnar 1st MC base to radial 2nd MC base	Prevents 1st metacarpal from translating radially
Posterior oblique	Trapezium to dorsal ulnar MC base	Secondary stabilizer
Ulnar collateral	Volar ulnar trapezium to ulnar MC base	Limits abduction and extension
Radial lateral	Radially on trapezium and MC base	Under the APL tendon/insertion
Finger		
• Gliding joints. 2nd & 3rd CMC have little motion, so minimal metacarpal fx angulation is acceptable b/c of immobility. 4th & 5th CMC have more anteroposterior motion, so more metacarpal fx angulation is acceptable b/c of mobility.		
Capsule	Base of metacarpal to carpus	Adds stability
CMC ligaments	Base of metacarpal to carpus	Dorsal (strongest), volar, interosseous ligaments
Intermetacarpal	Between adjacent metacarpal bases	Adds ulnar and radial stability to CMC joint


Anterior (palmar) view
Trapezium
Joint capsule
Collateral ligaments
Cut margins of digital fibrous sheaths
Flexor digitorum superficialis tendons *(cut)*
Pisiform
Hook of hamate
Palmar carpometacarpal ligaments
Palmar metacarpal ligaments
Deep transverse metacarpal ligaments
Volar plates (palmar ligaments)
Flexor digitorum profundus tendons

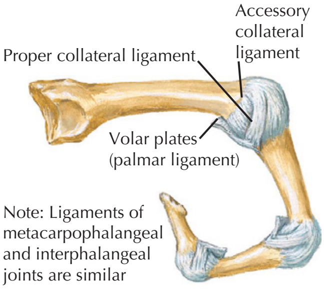
LIGAMENT	ATTACHMENTS	COMMENTS
METACARPOPHALANGEAL		
Thumb		
• Diarthrodial joint. Motion: primary = flexion & extension; secondary = rotation, adduction, abduction		
Capsule	Surrounds joint	Secondary stabilizer dorsally. Taut in flexion
Proper collateral	Center of metacarpal head to palmar proximal phalanx	Primary stabilizer. Taut in flexion, test in 30° flexion Ulnar collateral injured in "gamekeeper's/skier's" thumb
Accessory collateral	Palmar to proper collateral lig.	Taut in extension. Test integrity in extension.
Volar (palmar) **plate**	Palmar metacarpal head to palmar proximal phalanx base	Primary stabilizer in extension. Laxity in extension indicates injury to volar plate (+/− accessory collateral lig.)
Finger		
• Diarthrodial joint. Motion: primary = flexion & extension (ROM 0-90°); secondary = radial & ulnar deviation • Asymmetry of metacarpal head & collateral ligament origin result in "cam effect" (tight in flexion, loose in extension)		
Capsule	Surrounds joint	Secondary stabilizer; synovial reflections volar & dorsal
Proper collateral	Dorsal MC head to palmar P1 base	Primary stabilizer; tight in flexion, loose in extension
Accessory collateral	Palmar MC head to volar plate	Palmar to proper collaterals; stabilizes the volar plate
Volar (palmar) **plate**	Palmar MC head to palmar P1 base	Limits extension; volar support
Deep transverse (inter)**metacarpal**	Between adjacent metacarpal bases and MCPJ volar plates	Interconnects the volar plates, MCPJs, and metacarpals. Can prevent shortening of isolated metacarpal fractures.


Flexor digitorum profundus (FDP) tendon
Volar plate of PIPJ
Flexor digitorum superficialis (FDS) tendon
Proximal phalanx (P1)
Extensor tendon
[H]
[F]


Dorsal
Cleland's lig.
Lateral digital sheet
Neurovascular bundle
Digital a.
Digital n.
Grayson's lig.
Palmar


Accessory collateral ligament
Metacarpophalangeal (MP) joint
Metacarpal bone
Dorsal surface
Proper collateral ligament
Proximal interphalangeal (PIP) joint
Distal interphalangeal (DIP) joint
Palmar surface
Proximal
Middle
Distal
Phalanges
Volar plates (palmar ligament)

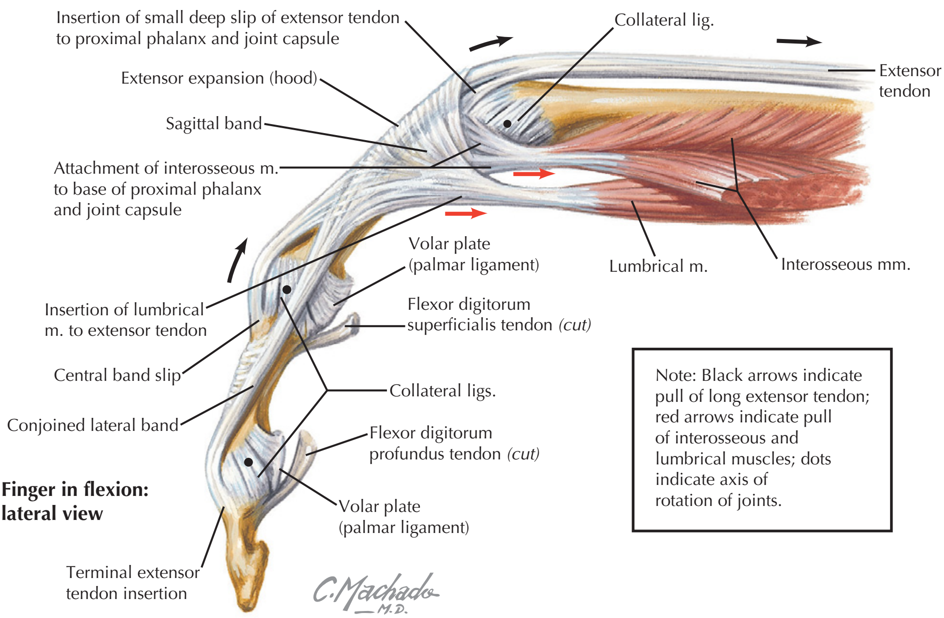
In extension: medial view


Accessory collateral ligament
Proper collateral ligament
Volar plates (palmar ligament)

Note: Ligaments of metacarpophalangeal and interphalangeal joints are similar

In flexion: medial view

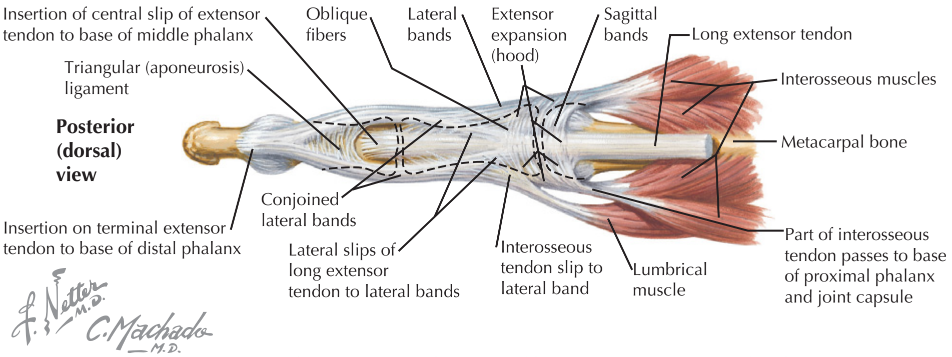
LIGAMENT	ATTACHMENTS	COMMENTS
PROXIMAL INTERPHALANGEAL		
• Hinge joints: Primary motion = flexion & extension (PIPJ: ROM 0-110°, DIPJ: ROM 0-60°). Minimal rotation or deviation motion. No "cam effect" in this joint. PIPJ is prone to stiffness/contracture after injury and/or immobilization.		
Capsule	Surrounds joint	Weak stabilizer esp. dorsally (central slip adds most support)
Proper collateral	Center of P1 head to volar P2	Primary stabilizer to deviation. Constant tension through ROM
Accessory collateral	Volar proximal phalanx head to volar plate (not bone)	Origin volar to axis of rotation: tight in ext., loose in flexion This can result in a contracture (do not immobilize in flexion)
Volar (palmar) **plate**	Volar middle phalanx to volar proximal phalanx (via check-rein ligaments)	Primary restraint to hyperextension. Firm distal attachment, looser proximal attachment (more prone to injury). Checkrein ligaments often contract after injury: contracture
OTHER INTERPHALANGEAL		
• Thumb interphalangeal (IPJ) and finger distal interphalangeal joints (DIPJ) • Hinge joints: Primary motion = flexion & extension (IPJ: ROM 0-90°; DIPJ: ROM 0-60°). Minimal rotation or deviation.		
Capsule	Surrounds joints	Weak stabilizer
Proper collateral	B/w adjacent phalanges	Similar to PIPJ, constant tension, no "cam effect"
Accessory collateral	Volar to collateral ligaments	Similar to PIPJ, less prone to contracture than PIPJ
Volar (palmar) **plate**	Volarly b/w phalanges	Primary restraint to hyperextension; can be injured
OTHER STRUCTURES		
Grayson's ligament	From flexor sheath to skin; volar to neurovascular bundle	Stabilizes skin & neurovascular bundle Involved in Dupuytren's disease/nodules
Cleland's ligament	From periosteum to skin	Stabilizes skin during flexion/extension; dorsal to NV bundle


Insertion of small deep slip of extensor tendon to proximal phalanx and joint capsule
Collateral lig.
Extensor tendon
Extensor expansion (hood)
Sagittal band
Attachment of interosseous m. to base of proximal phalanx and joint capsule
Volar plate (palmar ligament)
Lumbrical m.
Interosseous mm.
Insertion of lumbrical m. to extensor tendon
Flexor digitorum superficialis tendon *(cut)*
Central band slip
Collateral ligs.
Conjoined lateral band
Flexor digitorum profundus tendon *(cut)*
Volar plate (palmar ligament)
Terminal extensor tendon insertion
C.Machado M.D.

Finger in flexion: lateral view

Note: Black arrows indicate pull of long extensor tendon; red arrows indicate pull of interosseous and lumbrical muscles; dots indicate axis of rotation of joints.

MOTION	STRUCTURE	COMMENT
JOINT MOTION		
Metacarpophalangeal Joint		
Flexion	Interosseous muscles Lumbricals	Insert on proximal phalanx and lateral band (volar to rotation axis) Inserts on radial lateral band (volar to axis of rotation of MCPJ)
Extension	EDC via sagittal bands	Sagittal bands insert on volar plate, creating a "lasso" around proximal phalanx base and extend joint through the lasso. EDC has minimal attachment to P1 (which does not extend the joint) but extends joints via the sagittal bands.
Proximal Interphalangeal Joint		
Flexion	Flexor digitorum superficialis (FDS) Flexor digitorum profundus (FDP)	Primary PIPJ flexor via insertion on middle phalanx volar base Secondary PIPJ flexor
Extension	EDC via the central slip (band) Lumbricals via lateral bands	Central slip of EDC inserts on dorsal P2 base to extend PIPJ Has attachment to radial lateral band (dorsal to rotation axis)
Distal Interphalangeal Joint		
Flexion	Flexor digitorum profundus (FDP)	Tendon attaches at P3 volar base, pulls through tendon sheath
Extension	EDC via terminal extensor tendon Oblique retinacular ligament (ORL)	Lateral bands converge at terminal insertion on dorsal P3 base Links PIPJ & DIPJ extension; extends DIPJ as PIPJ is extended


Insertion of central slip of extensor tendon to base of middle phalanx
Oblique fibers
Lateral bands
Extensor expansion (hood)
Sagittal bands
Long extensor tendon
Triangular (aponeurosis) ligament
Interosseous muscles
Posterior (dorsal) view
Metacarpal bone
Conjoined lateral bands
Insertion on terminal extensor tendon to base of distal phalanx
Lateral slips of long extensor tendon to lateral bands
Interosseous tendon slip to lateral band
Lumbrical muscle
Part of interosseous tendon passes to base of proximal phalanx and joint capsule
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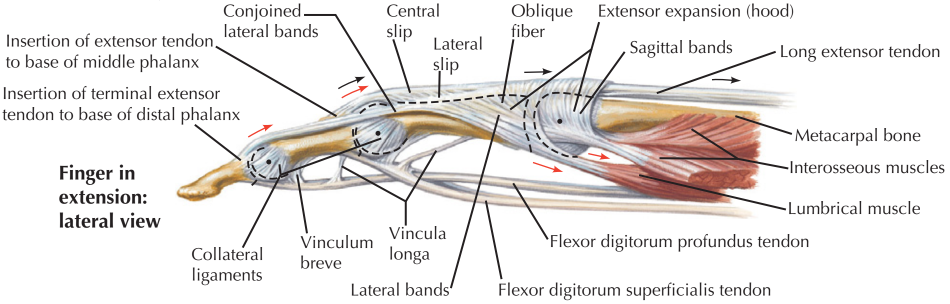
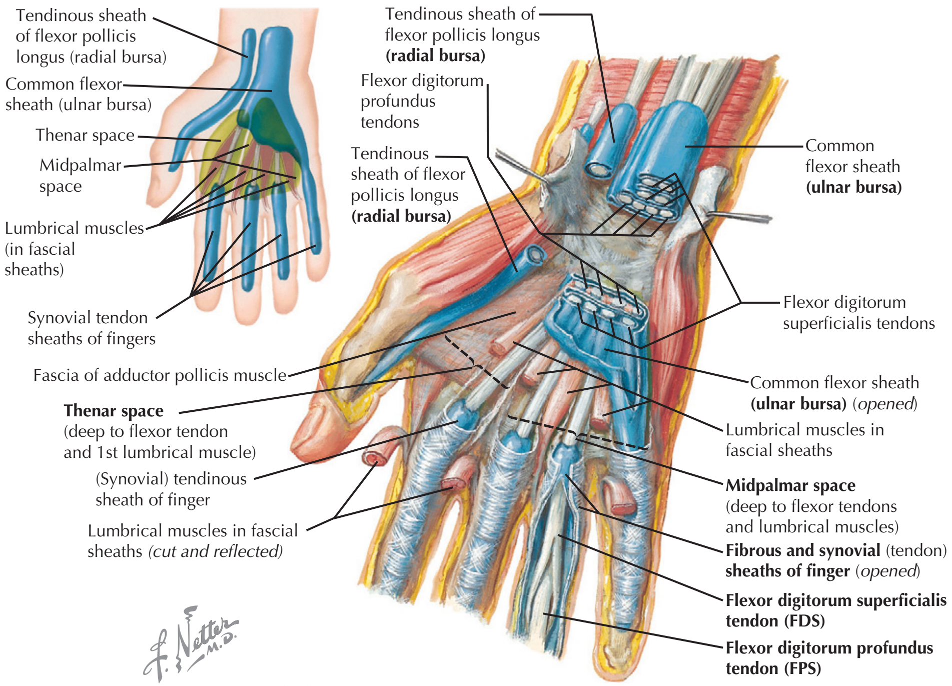
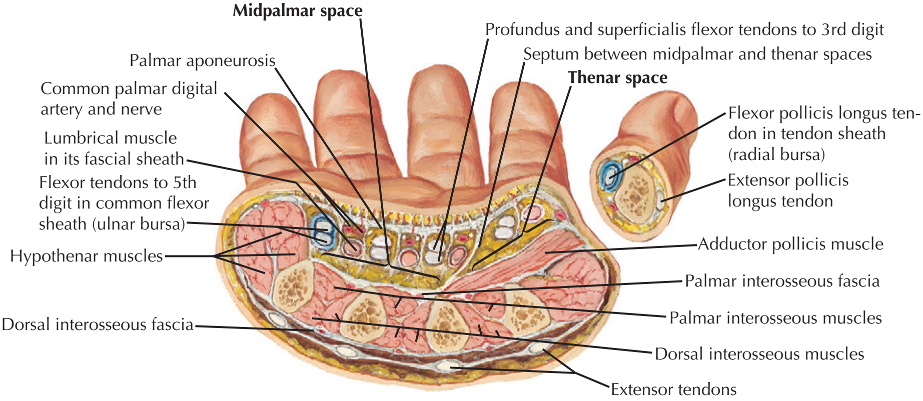
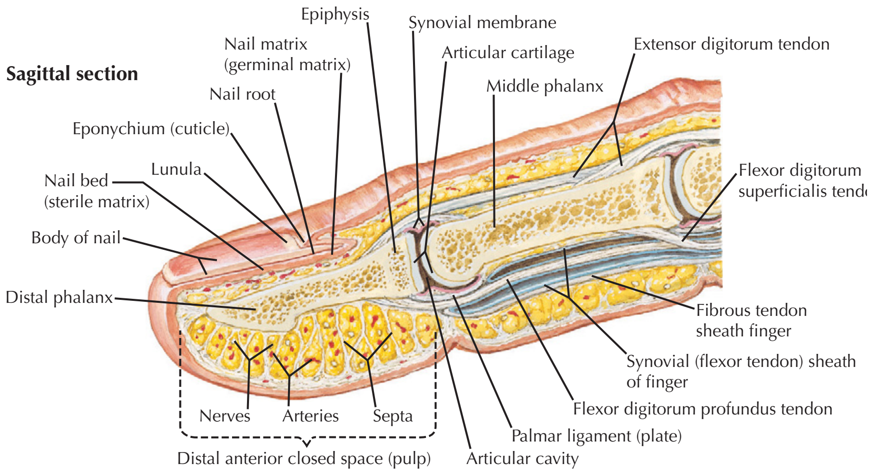

Conjoined lateral bands
Central slip
Oblique fiber
Extensor expansion (hood)
Insertion of extensor tendon to base of middle phalanx
Lateral slip
Sagittal bands
Long extensor tendon
Insertion of terminal extensor tendon to base of distal phalanx
Metacarpal bone
Interosseous muscles
Finger in extension: lateral view
Lumbrical muscle
Vincula longa
Collateral ligaments
Vinculum breve
Flexor digitorum profundus tendon
Lateral bands
Flexor digitorum superficialis tendon

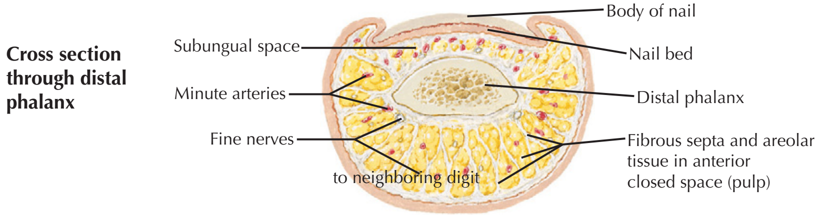
STRUCTURE	DESCRIPTION	COMMENT
INTRINSIC APPARATUS		
• **Dorsal Extensor Aponeurosis** (also called dorsal expansion, dorsal hood, extensor hood)		
◦ Sagittal band	Inserts on volar plate (P1); extensor tendon (EDC) glides under it	Extends MCPJ via "lasso" around P1 base; radial sagittal bands are weaker, may rupture
◦ Oblique fibers	Covers MCPJ and base of proximal phalanx	Holds EDC centered over MCPJ
◦ Lateral bands	Lateral hood fibers join tendinous portion of interossei/lumbricals to form lateral bands	Volar to MCPJ axis: flexes MCPJ Dorsal to PIPJ axis: extends PIPJ
• **Extrinsic Extensor Tendon (EDC)** glides under the dorsal hood (to extend MCP) before trifurcating at prox. phalanx		
◦ Lateral slip	EDC trifurcates over P1 giving two lateral slips	These slips conjoin with lateral bands
◦ Central slip	Central slip of trifurcation; inserts base of P2	Extends PIPJ; torn in boutonniere injury
◦ Terminal extensor tendon	Confluence of two conjoined lateral bands on dorsal base of distal phalanx (P3)	Extends DIPJ via insertion on dorsal base of P3; avulsed in mallet finger injury
• Conjoined lateral band	Confluence of EDC lateral slips and lateral bands from extensor aponeurosis	Both join distally to make terminal extensor tendon
• Transverse retinacular ligaments	From PIPJ volar plate and flexor sheath to both conjoined lateral bands	Prevents conjoined lateral band dorsal subluxation during PIPJ extension
• Triangular ligament (aponeurosis)	Transverse bands over P2, connects both conjoined lateral bands and terminal tendon	Prevents lateral band volar subluxation in PIPJ flexion; torn in boutonniere injury
• Oblique retinacular ligament (ORL)	From volar P1 to dorsal P3/terminal tendon	Extends DIPJ when PIPJ is extended
OTHER STRUCTURES		
Junctura tendinae	Tendinous connections between ECD tendons to adjacent fingers proximal to MCPJ	Prevents full extension of finger when adjacent digit is flexed (see page 155)

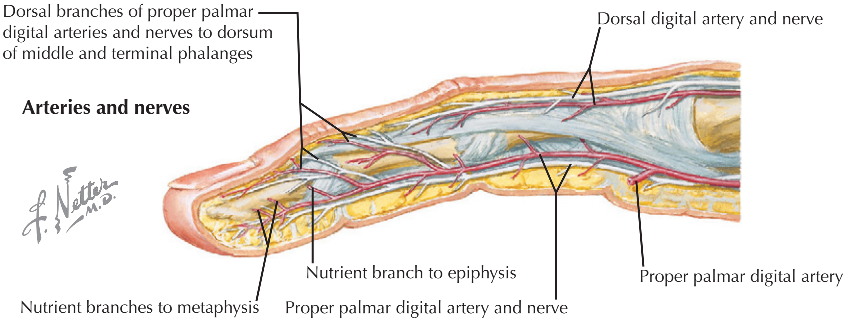

Tendinous sheath of flexor pollicis longus (radial bursa)
Common flexor sheath (ulnar bursa)
Thenar space
Midpalmar space
Lumbrical muscles (in fascial sheaths)
Synovial tendon sheaths of fingers
Tendinous sheath of flexor pollicis longus (radial bursa)
Flexor digitorum profundus tendons
Tendinous sheath of flexor pollicis longus (radial bursa)
Common flexor sheath (ulnar bursa)
Flexor digitorum superficialis tendons
Fascia of adductor pollicis muscle
Thenar space (deep to flexor tendon and 1st lumbrical muscle)
(Synovial) tendinous sheath of finger
Lumbrical muscles in fascial sheaths (cut and reflected)
Common flexor sheath (ulnar bursa) (opened)
Lumbrical muscles in fascial sheaths
Midpalmar space (deep to flexor tendons and lumbrical muscles)
Fibrous and synovial (tendon) sheaths of finger (opened)
Flexor digitorum superficialis tendon (FDS)
Flexor digitorum profundus tendon (FPS)


Midpalmar space
Palmar aponeurosis
Common palmar digital artery and nerve
Lumbrical muscle in its fascial sheath
Flexor tendons to 5th digit in common flexor sheath (ulnar bursa)
Hypothenar muscles
Dorsal interosseous fascia
Profundus and superficialis flexor tendons to 3rd digit
Septum between midpalmar and thenar spaces
Thenar space
Flexor pollicis longus tendon in tendon sheath (radial bursa)
Extensor pollicis longus tendon
Adductor pollicis muscle
Palmar interosseous fascia
Palmar interosseous muscles
Dorsal interosseous muscles
Extensor tendons

HAND SPACES		
STRUCTURE	**CHARACTERISTICS**	**COMMENT**
Thenar space	Between flexor tendons and adductor pollicis	Potential space: site of possible infection
Midpalmar space	Between flexor tendons and metacarpals	Potential space: site of possible infection
Parona's space	Between flexor tendons and pronator quadratus. Thumb and SF flexor sheaths communicate here	Potential space: "horseshoe" abscess can occur here as infection tracks proximally
Radial bursa	Proximal extension of FPL sheath	Infection can track proximally
Ulnar bursa	Communicates with SF FDS/FDP flexor tendon sheath	Flexor sheath infection can track proximally into bursa


Sagittal section
Epiphysis
Synovial membrane
Nail matrix (germinal matrix)
Articular cartilage
Extensor digitorum tendon
Middle phalanx
Nail root
Eponychium (cuticle)
Lunula
Nail bed (sterile matrix)
Flexor digitorum superficialis tend
Body of nail
Distal phalanx
Fibrous tendon sheath finger
Synovial (flexor tendon) sheath of finger
Flexor digitorum profundus tendon
Nerves
Arteries
Septa
Palmar ligament (plate)
Distal anterior closed space (pulp)
Articular cavity


Cross section through distal phalanx
Body of nail
Subungual space
Nail bed
Minute arteries
Distal phalanx
Fine nerves
Fibrous septa and areolar tissue in anterior closed space (pulp)
to neighboring digit


Dorsal branches of proper palmar digital arteries and nerves to dorsum of middle and terminal phalanges
Dorsal digital artery and nerve
Arteries and nerves
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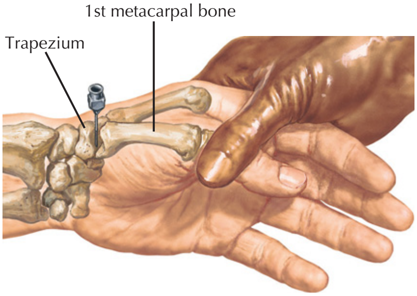
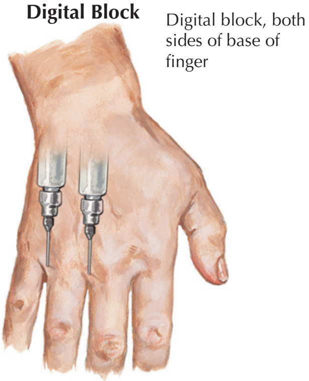
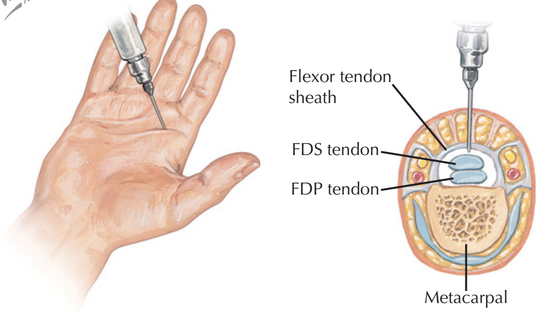
Nutrient branch to epiphysis
Proper palmar digital artery
Nutrient branches to metaphysis
Proper palmar digital artery and nerve

STRUCTURE	CHARACTERISTICS	COMMENT
	FINGERTIP	
Nail	Cornified epithelium	If completely avulsed, consider replacing to prevent eponychium and matrix adhesions
Nail bed/matrix		
Germinal	Under eponychium and nail to edge of lunula	Where nail grows (1mm a week), must be intact (repaired) for normal nail growth
Sterile	Under nail, distal to lunula	Adheres to nail. Repair may prevent nail deformity.
Pulp	Multiple septa, nerves, arteries	Felon is an infection of the pulp
Paronychia	Radial and ulnar nail folds	Common site of infection
Eponychia	Proximal nail fold	Common site of infection

- The digital artery is superficial/volar to the nerve proximally but runs dorsal to the nerve in the finger.
- Volar neurovascular bundle supplies the distal finger and fingertip.


Thumb CMC Injection


Digital Block


Flexor Sheath Injection

STEPS

INJECTION OF THUMB CMC JOINT

1. Ask patient about allergies
2. Palpate thumb CMC joint on volar radial aspect
3. Prepare skin over CMC joint (iodine/antiseptic soap)
4. Anesthetize skin locally (quarter size spot)
5. Palpate base of thumb MC, pull axial distraction on thumb with slight flexion to open joint. Use 22 gauge or smaller needle, and insert into joint (if available use an image intensifier to confirm needle is in joint). Aspirate to ensure needle is not in a vessel. Inject 1-2 ml of 1:1 local (without epinephrine) /corticosteroid preparation into CMC joint. (The fluid should flow easily if needle is in joint)
6. Dress injection site

FLEXOR TENDON SHEATH BLOCK

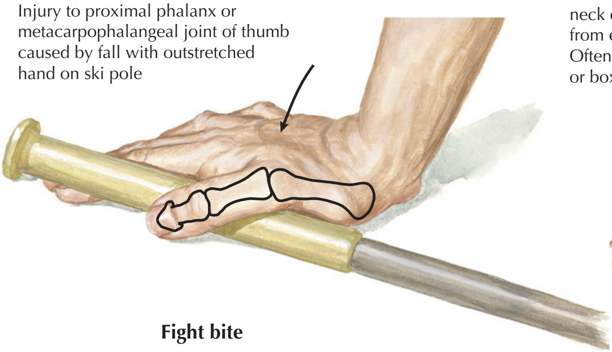
1. Ask patient about allergies
2. Palpate the flexor tendon at the distal palmar crease over metacarpal head/A1 pulley.
3. Prepare skin over palm (iodine/antiseptic soap)
4. Insert 25 gauge needle into flexor tendon at the level of the distal palmar crease. Withdraw needle very slightly so that it is just outside tendon, but inside sheath. Inject 2-3ml of local anesthetic without epinephrine. (Add corticosteroid if injecting for trigger finger).
5. Dress injection site

DIGITAL/METACARPAL BLOCK

1. Prepare skin over dorsal proximal finger web space (iodine/antiseptic soap)
2. Insert 25 gauge needle between metacarpal necks (metacarpal block) or on either side of proximal phalanx (digital block) in digital web space. Aspirate to ensure that needle is not in a vessel. Inject 1-2ml of local anesthetic (without epinephrine) on both sides of the bones. Consider injecting local anesthetic dorsally over the bone as well.
3. Care should be taken not to inject too much fluid into the closed space of the proximal digit.
4. Dress injection site

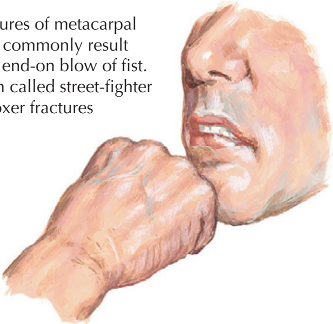
Fractures and dislocations of thumb

Injury to proximal phalanx or metacarpophalangeal joint of thumb caused by fall with outstretched hand on ski pole



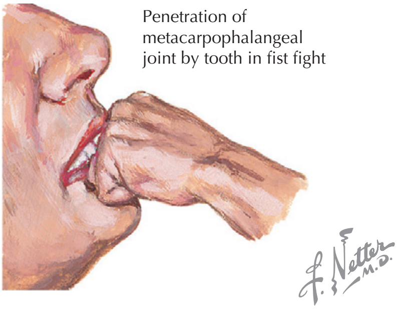
Boxer fracture

Fractures of metacarpal neck commonly result from end-on blow of fist. Often called street-fighter or boxer fractures

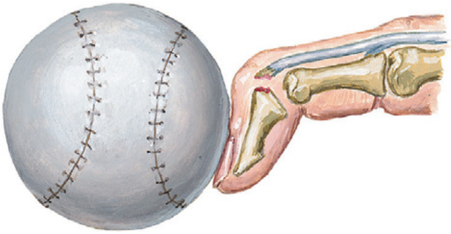


Fight bite

Penetration of metacarpophalangeal joint by tooth in fist fight



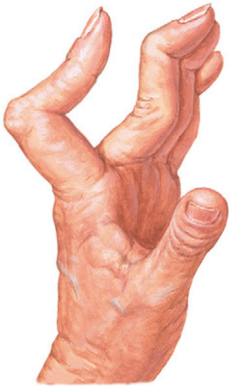
Mallet finger



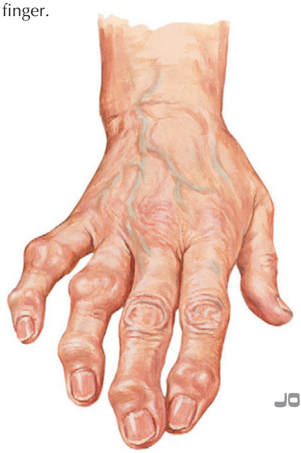
Usually caused by direct blow on extended distal phalanx, as in baseball, volleyball

QUESTION	ANSWER	CLINICAL APPLICATION
1. Hand dominance	Right or left	Dominant hand injured more often
2. Age	Young Middle age-elderly	Trauma, infection Arthritis, nerve entrapments
3. Pain		
a. Onset	Acute Chronic	Trauma, infection Arthritis
b. Location	CMC (thumb) Joints (MCPs, IPs) Volar (fingers)	Arthritis (OA) especially in women Arthritis (osteoarthritis, rheumatoid) Purulent tenosynovitis (+ Kanavel signs)
4. Stiffness	In AM, "catching" Catching/clicking	Rheumatoid arthritis Trigger finger
5. Swelling	After trauma No trauma	Infection (e.g., purulent tenosynovitis, felon, paronychia) Trigger finger, arthritides, gout, tendinitis
6. Mass		Ganglion, Dupuytren's contracture, giant cell tumor
7. Trauma	Fall, sports injury Open wound	Fracture, dislocation, tendon avulsion, ligament injury Infection
8. Activity	Sports, mechanical	Trauma (e.g., fracture, dislocation, tendon or ligament injury)
9. Neurologic symptoms	Pain, numbness, tingling Weakness	Nerve entrapment (e.g., carpal tunnel), thoracic outlet syndrome, radiculopathy (cervical) Nerve entrapment (usually in wrist or more proximal)
10. History of arthritides	Multiple joints involved	Rheumatoid arthritis, Reiter's syndrome, etc.

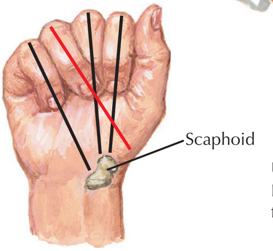
Rheumatoid arthritis
Boutonniere deformity of index finger with swan-neck deformity of other fingers



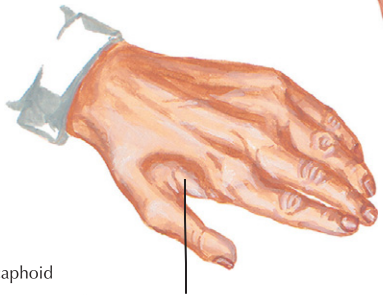
Osteoarthritis
Heberden's nodes seen in index and middle finger distal interphalangeal joints. Bouchards nodes seen in proximal interphlangeal joints of the ring and small finger.



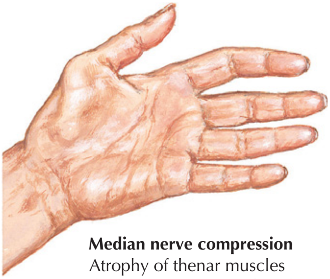
JOHN A.CRAIG AD
F. Netter M.D.



Rotation displacement of ring finger. All fingers should point toward scaphoid when clenched



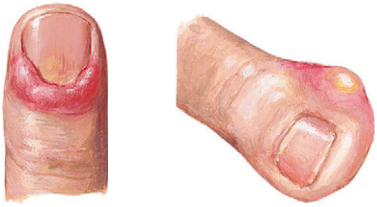
Ulnar nerve compression
Interosseous muscle wasting from ulnar nerve compression



Median nerve compression
Atrophy of thenar muscles due to compression of median nerve

EXAMINATION	TECHNIQUE	CLINICAL APPLICATION
	INSPECTION	
Gross deformity	Ulnar drift/swan neck, boutonniere Rotational or angular deformity	Rheumatoid arthritis Fracture
Finger position	Flexion Rotation of digit	Dupuytren's contracture, purulent tenosynovitis Fracture (acute), fracture malunion
Skin, hair, nail changes	Cool, hairless, spoon, etc	Neurovascular disorders: Raynaud's, diabetes, nerve injury
Swelling	DIPs PIPs MCPs Fusiform shape finger	Osteoarthritis: Heberden's nodes (at DIPs: #1), Bouchard's nodes (at PIPs) Rheumatoid arthritis Purulent tenosynovitis
Muscle wasting	Thenar eminence Hypothenar eminence/intrinsics	Median nerve injury, CTS, C8/T1 pathology Ulnar nerve injury (e.g., cubital tunnel syndrome)

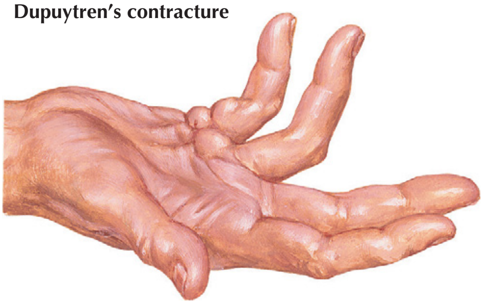
Infections of the fingers



Paronychia

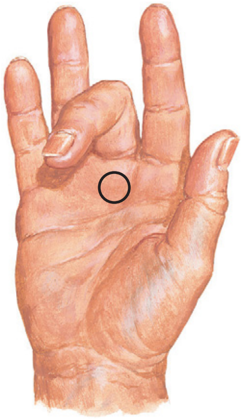
Felon

Dupuytren's contracture



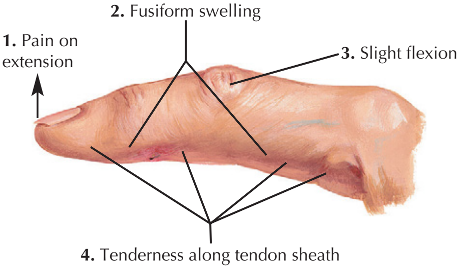
Flexion contracture of 4th and 5th fingers (most common). Dimpling and puckering of skin. Palpable fascial nodules near flexion crease of palm at base of involved fingers with cordlike formations extending to proximal palm

Stenosing tenosynovitis (trigger finger)

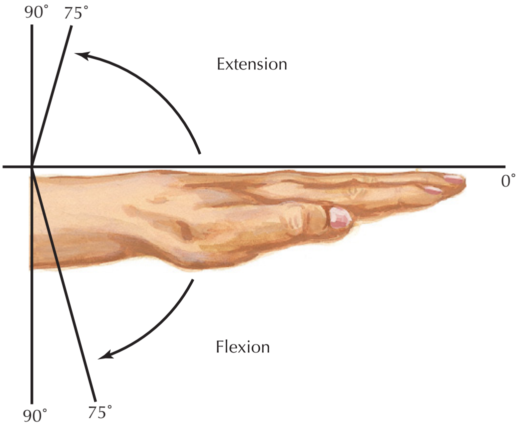


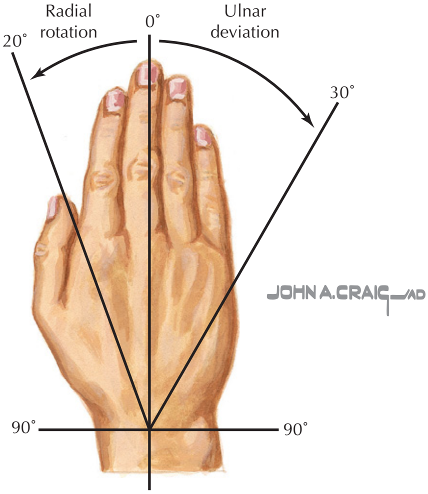
Patient unable to extend affected finger. It can be extended passively, and extension occurs with distinct and painful snapping action. Circle indicates point of tenderness where nodular enlargement of tendons and sheath is usually palpable

Purulent tenosynovitis. Four cardinal signs of Kanavel

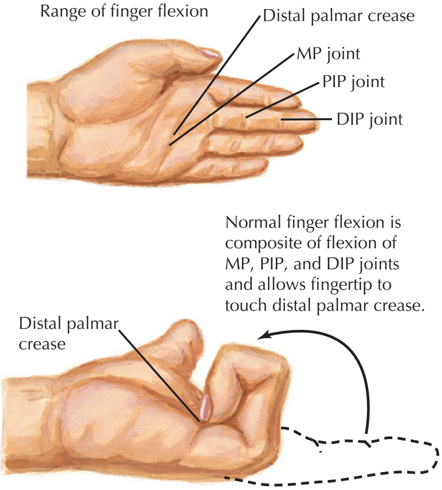


EXAMINATION	TECHNIQUE	CLINICAL APPLICATION
PALPATION		
Skin	Warm, red Cool, dry	Infection Neurovascular compromise
Metacarpals	Each along its length	Tenderness may indicate fracture
Phalanges and finger joints	Each separately	Tenderness: fracture, arthritis Swelling: arthritis
Soft tissues	Thenar eminence Hypothenar eminence Palm (palmar fascia) Flexor tendons: along volar finger All aspects of finger tip	Wasting indicates median nerve injury Wasting indicates ulnar nerve injury Nodules: Dupuytren's contracture; snapping A1 pulley with finger extension: trigger finger Tenderness suggests purulent tenosynovitis Tenderness: paronychia or felon


90° 75°
Extension
0°
Flexion
90° 75°

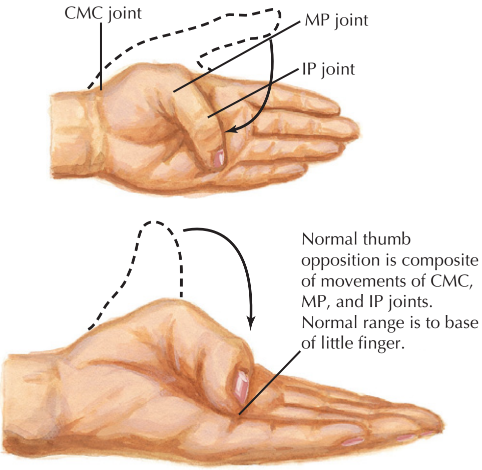

Radial rotation
0°
Ulnar deviation
20°
30°
JOHN A.CRAIG_AD
90°
90°

Range of finger flexion


Distal palmar crease
MP joint
PIP joint
DIP joint
Distal palmar crease

Normal finger flexion is composite of flexion of MP, PIP, and DIP joints and allows fingertip to touch distal palmar crease.

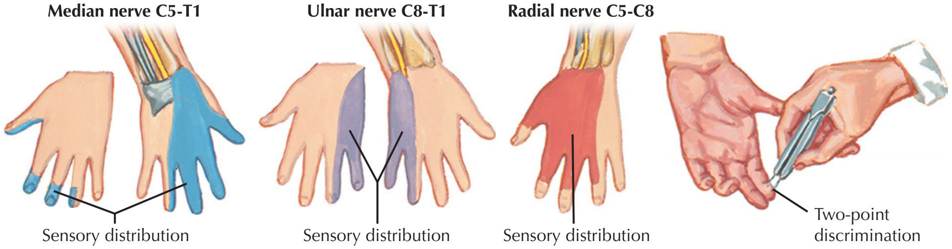
Range of thumb opposition


CMC joint
MP joint
IP joint

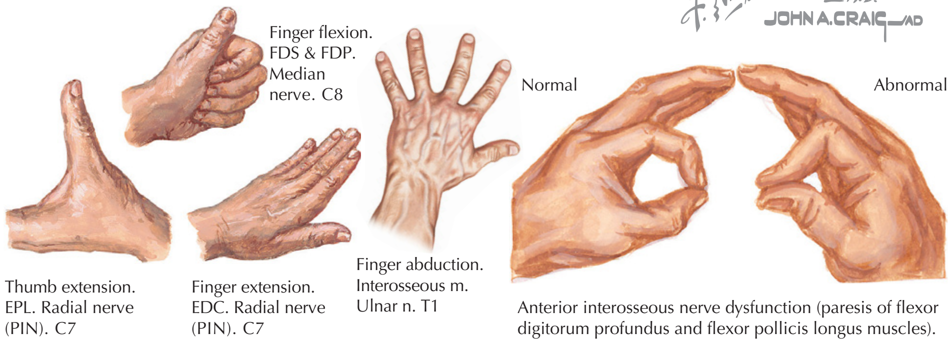
Normal thumb opposition is composite of movements of CMC, MP, and IP joints. Normal range is to base of little finger.

EXAMINATION	TECHNIQUE	CLINICAL APPLICATION
RANGE OF MOTION		
Finger		
MCP joint	Flex 90°, extend 0°, adduct/abduct 0-20°	Decreased flexion if casted in extension (collateral ligaments shorten)
PIP joint	Flex 110°, extend 0°	Hyperextension leads to swan neck
DIP joint	Flex 80°, extend 10°	All fingers should point to scaphoid at full flexion
Thumb		
CMC joint	Radial abduction: flex 50°, extend 50° Palmar abduction: abduct 70, adduct 0°	Motion is in plane of palm Motion is perpendicular to plane of the palm
MCP joint	In plane of palm: flex 50°, extend 0°	
IP joint	In plane of palm: flex 75°, extend 10°	
Opposition	Touch thumb to small finger base	Motion is mostly at CMC joint

Sensory testing

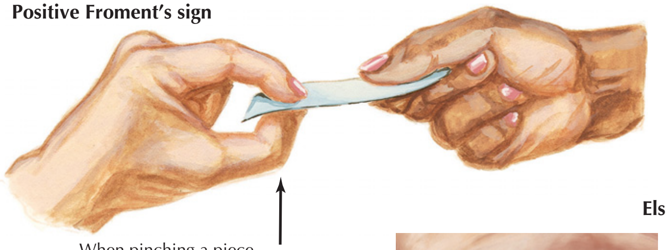

Median nerve C5-T1
Ulnar nerve C8-T1
Radial nerve C5-C8
Sensory distribution
Sensory distribution
Sensory distribution
Two-point discrimination

Motor testing


Finger flexion. FDS & FDP. Median nerve. C8
Normal
Abnormal
Thumb extension. EPL. Radial nerve (PIN). C7
Finger extension. EDC. Radial nerve (PIN). C7
Finger abduction. Interosseous m. Ulnar n. T1
Anterior interosseous nerve dysfunction (paresis of flexor digitorum profundus and flexor pollicis longus muscles).

EXAMINATION	TECHNIQUE	CLINICAL APPLICATION
NEUROVASCULAR		
Sensory		
Radial nerve (C6)	Dorsal thumb, web space	Deficit indicates corresponding nerve/root lesion
Median nerve (C6-7)	Radial border, index finger	Deficit indicates corresponding nerve/root lesion
Ulnar nerve (C8)	Ulnar border, small finger	Deficit indicates corresponding nerve/root lesion
Motor		
Radial nerve/PIN (C7)	Finger MCP extension Thumb abduction/extension	Weakness = Extensor digitorum or nerve lesion Weakness = APL/EPL or nerve/root lesion
Median nerve (C8)	Finger PIP flexion	Weakness = FDS or corresponding nerve/root lesion
AIN	Index finger DIP flexion Thumb IP flexion	Weakness = FDP or AIN nerve lesion Weakness = FPL or corresponding nerve/root lesion
Motor recurrent branch	Thumb opposition	Weakness = APB, OP, 1/2 FPB or nerve lesion; (CTS)
Ulnar nerve (deep branch) (T1)	Finger abduction Thumb adduction	Weakness = Dorsal/volar interosseous or nerve lesion Weakness = Adductor pollicis or nerve/root lesion
Reflex		
Hoffman's	Flick MF DIPJ into flexion	Pathologic if thumb IPJ flexes: myelopathy
Vascular		
Capillary refill	Squeeze finger tip	Color (blood) should return in less than 2 seconds
Allen's test	Occlude both radial & ulnar arteries, then release one	Hand should "pink up" if artery that was released AND arches are patent. Failure to "pink up" = arterial injury
Doppler	Arches, digital borders	Use if presence of pulses/patent vessels is in question

Positive Froment's sign



When pinching a piece of paper between thumb and index finger, the thumb IP joint will flex if the adductor pollicis muscle is weak (ulnar nerve paralysis).

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K. Marzen
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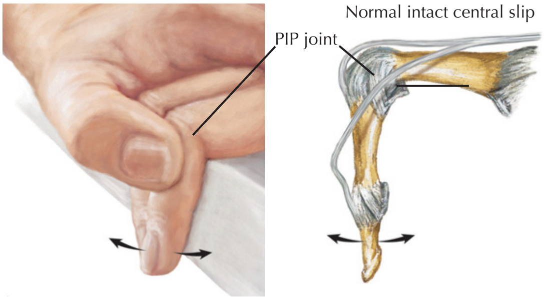
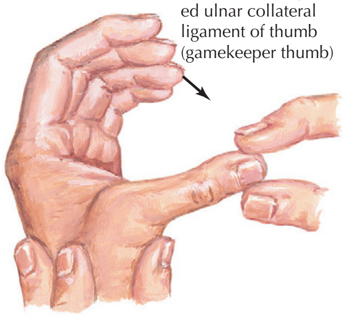
Elson test

Normal intact central slip

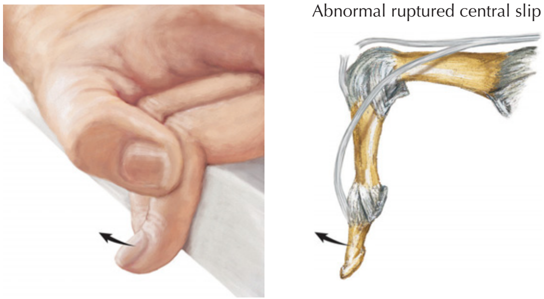


Thumb instability test

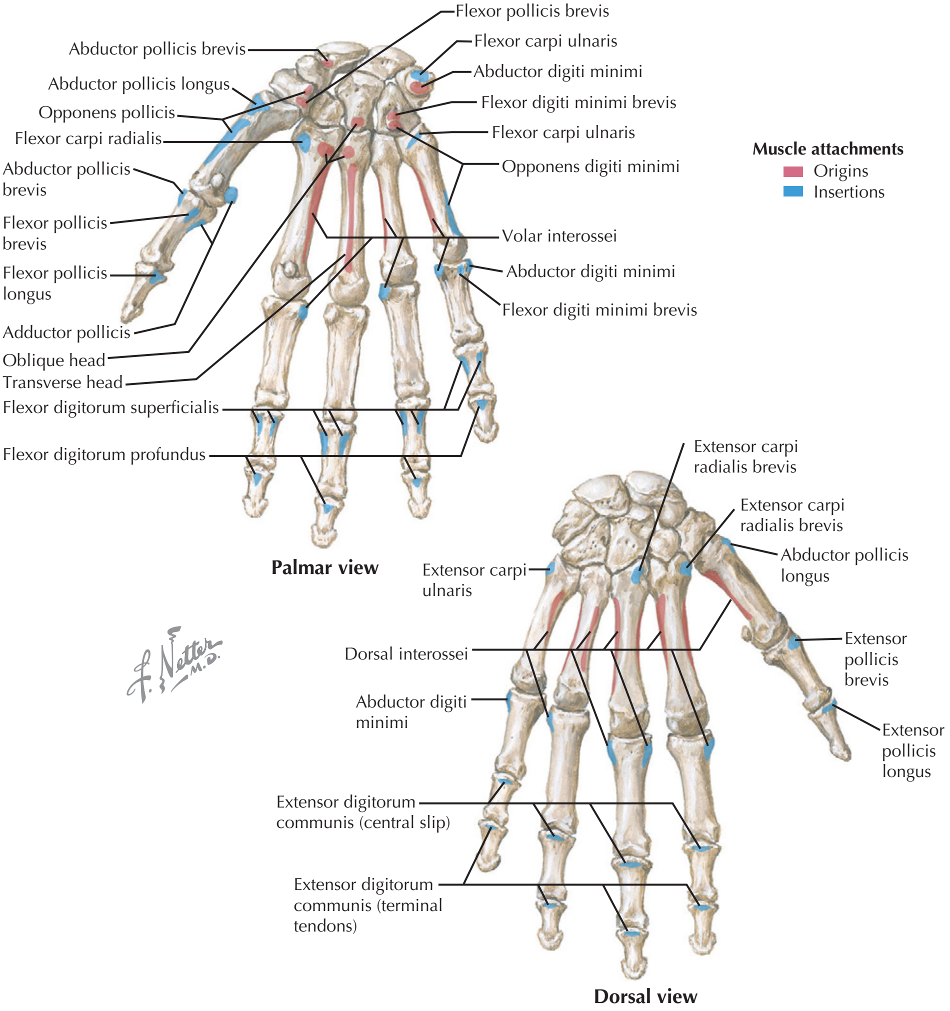
Stress test for ruptured ulnar collateral ligament of thumb (gamekeeper thumb)



Abnormal ruptured central slip



EXAMINATION	TECHNIQUE	CLINICAL APPLICATION
	SPECIAL TESTS	
Profundus test	Stabilize PIPJ in extension, flex DIPJ only	Inability to flex DIP alone indicates FDP pathology
Sublimus test	Extend all fingers, flex a single finger at PIPJ	Inability to flex PIP of isolated finger indicates FDS pathology
Froment's sign	Hold paper with thumb and index finger, pull paper	If thumb IP flexion is positive, suggest adductor pollicis weakness and/or ulnar nerve palsy
CMC grind test	Axial compress and rotate CMC joint	Pain indicates arthritis at CMC joint of thumb
Finger instability test	Stabilize proximal joint, apply varus and valgus stress	Laxity indicates collateral ligament injury
Thumb instability test	Stabilize MCP, apply valgus stress in extension and 30° of flexion	Laxity at 30°: ulnar collateral ligament injury Laxity in extension: accessory collateral ligament and/or volar plate injury
Bunnell-Littler test	Extend MCPJ, passively flex PIPJ	Tight or inability to flex PIPJ, improved with MCPJ flexion indicates tight intrinsic muscles
Elson test	Flex PIPJ 90° over table edge, resist P2 extension	DIPJ rigidly extending (via lateral bands) indicates central slip injury (boutonnière)


Flexor pollicis brevis
Abductor pollicis brevis
Flexor carpi ulnaris
Abductor digiti minimi
Abductor pollicis longus
Opponens pollicis
Flexor digiti minimi brevis
Flexor carpi radialis
Flexor carpi ulnaris
Opponens digiti minimi
Abductor pollicis brevis
Flexor pollicis brevis
Volar interossei
Flexor pollicis longus
Abductor digiti minimi
Flexor digiti minimi brevis
Adductor pollicis
Oblique head
Transverse head
Flexor digitorum superficialis
Flexor digitorum profundus
Muscle attachments
🟥 Origins
🟦 Insertions
Extensor carpi radialis brevis
Extensor carpi radialis brevis
Abductor pollicis longus
Extensor carpi ulnaris
Dorsal interossei
Extensor pollicis brevis
Abductor digiti minimi
Extensor pollicis longus
Extensor digitorum communis (central slip)
Extensor digitorum communis (terminal tendons)
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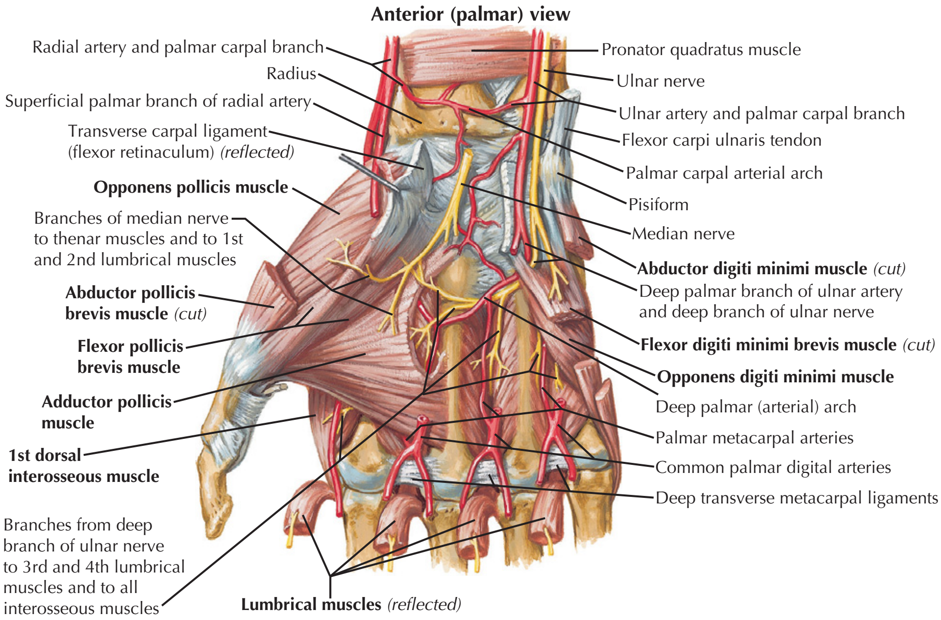
Palmar view

Dorsal view

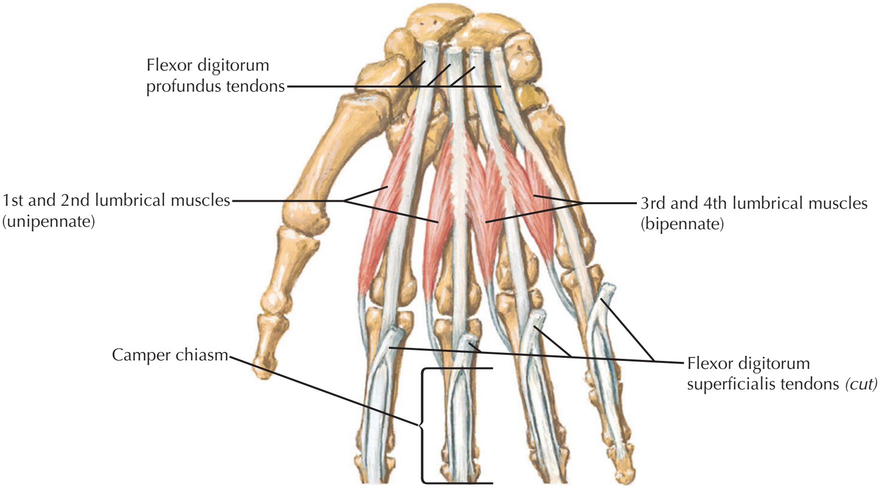
CARPUS	METACARPAL	PHALANGES—DORSAL	PHALANGES—PLANTAR
Trapezium Abductor pollicis brevis Flexor pollicis brevis Opponens pollicis **Capitate** Adductor pollicis **Hamate** Flex. digiti minimi brevis Opponens digiti minimi **Pisiform** Abductor digiti minimi	Dorsal interosseous Palmar interosseous Adductor pollicis Abd. pollicis longus Opponens pollicis Opp. digiti minimi Flexor carpi radialis Flexor carpi ulnaris Ext. carpi rad. longus Ext. carpi rad. brevis Extensor carpi ulnaris	**Proximal phalanx** Ext. pollicis brevis (thumb) Dorsal interossei Abductor digiti minimi **Middle phalanx** Extensor digitorum communis (central slip) **Distal phalanx** Ext. pollicis longus (thumb) Extensor digitorum communis (terminal tendon)	**Proximal phalanx** Abductor pollicis brevis (thumb) Flexor pollicis brevis (thumb) Adductor pollicis (thumb) Palmar interossei Flexor digiti minimi brevis Abductor digiti minimi **Middle phalanx** Flexor digitorum superficialis **Distal phalanx** Flexor pollicis longus (thumb) Flexor digitorum profundus
Lumbricals originate on flexor digitorum profundus [FDP] tendon and insert on the radial lateral bands			


Anterior (palmar) view
Radial artery and palmar carpal branch
Radius
Superficial palmar branch of radial artery
Transverse carpal ligament (flexor retinaculum) (reflected)
Opponens pollicis muscle
Branches of median nerve to thenar muscles and to 1st and 2nd lumbrical muscles
Abductor pollicis brevis muscle (cut)
Flexor pollicis brevis muscle
Adductor pollicis muscle
1st dorsal interosseous muscle
Branches from deep branch of ulnar nerve to 3rd and 4th lumbrical muscles and to all interosseous muscles
Lumbrical muscles (reflected)
Pronator quadratus muscle
Ulnar nerve
Ulnar artery and palmar carpal branch
Flexor carpi ulnaris tendon
Palmar carpal arterial arch
Pisiform
Median nerve
Abductor digiti minimi muscle (cut)
Deep palmar branch of ulnar artery and deep branch of ulnar nerve
Flexor digiti minimi brevis muscle (cut)
Opponens digiti minimi muscle
Deep palmar (arterial) arch
Palmar metacarpal arteries
Common palmar digital arteries
Deep transverse metacarpal ligaments

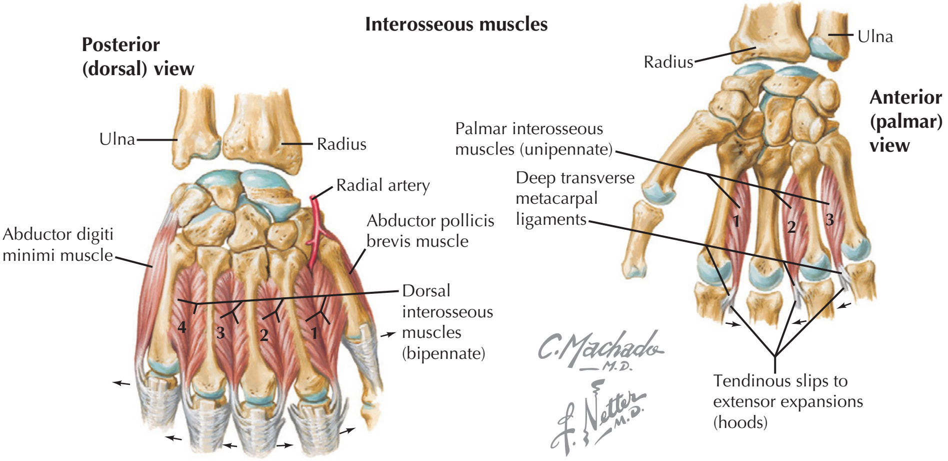
MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
		THENAR COMPARTMENT			
Abductor pollicis brevis (APB)	Scaphoid, trapezium	Lateral prox. phalanx (thumb)	Median	Palmar pronation	Primary muscle in opposition
Flexor pollicis brevis 1. Superficial head 2. Deep head	 Trans. carpal lig. Trapezium	 Base of thumb Proximal phalanx	 Median Ulnar	Thumb MPC flexion	Muscle has dual innervations
Opponens pollicis	Trapezium	Lateral thumb MC	Median	Oppose (flex/abduct) thumb	Pronates/stabilizes thumb MC
		ADDUCTOR COMPARTMENT			
Adductor pollicis 1. Oblique head 2. Transverse head	1. Capitate, 2nd and 3rd MC 2. 3rd metacarpal	Ulnar base of proximal phalanx of thumb	Ulnar	Thumb adduction and thumb MCP flexion	Test function with Froment's test
		HYPOTHENAR COMPARTMENT			
Palmaris brevis [PB]	Transverse carpal ligament [TCL]	Skin on medial palm	Ulnar	Wrinkles skin	Protects ulnar nerve
Abductor digiti minimi [ADQ]	Pisiform (FCU tendon)	Ulnar base of prox. phalanx	Ulnar	SF abduction	Ulnar nerve and artery under it
Flexor digiti minimi brevis [FDMB]	Hamate, TCL	Base of proximal phalanx of SF	Ulnar	SF MCP flexion	Deep to ADQ and nerve
Opponens digiti minimi [ODQ]	Hamate, TCL	Ulnar side 5th metacarpal	Ulnar	Oppose (flex and supinate) SF	Deep to other muscles

- Abductor muscles are superficial; opponens muscles are deep
- Motor recurrent branch of median innervates thenar muscle and radial 2 lumbricals
- Deep branch at ulnar nerve innervates hypothenar, adductor pollicis, interossei, and ulnar 2 lumbricals

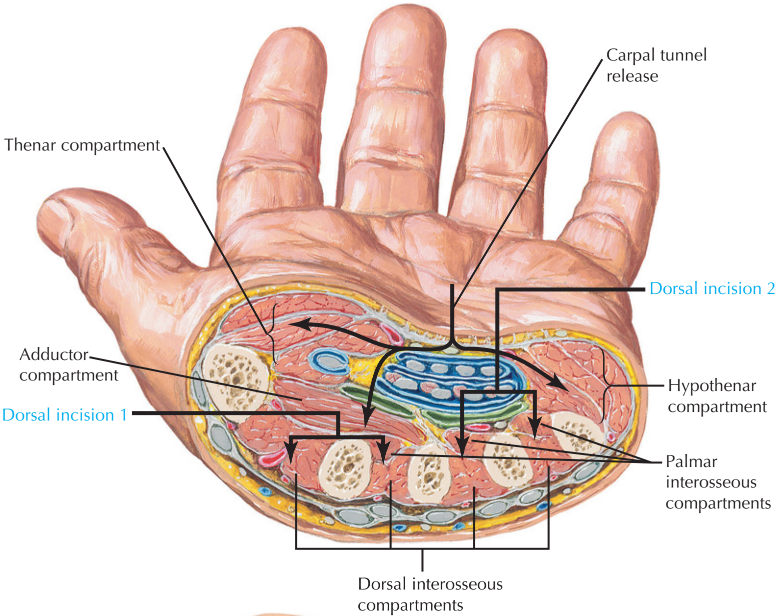
Lumbrical muscles

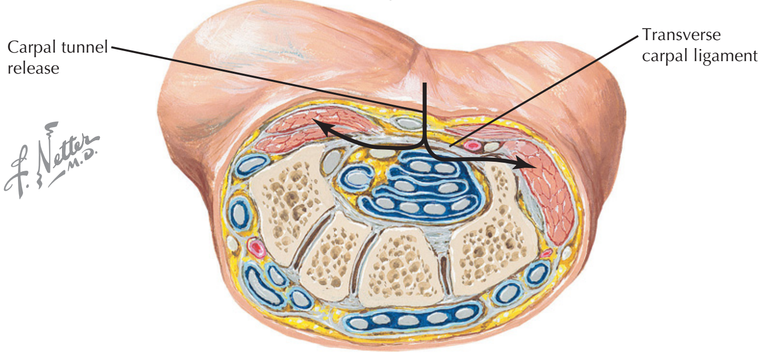

Flexor digitorum profundus tendons
1st and 2nd lumbrical muscles (unipennate)
3rd and 4th lumbrical muscles (bipennate)
Camper chiasm
Flexor digitorum superficialis tendons *(cut)*

Interosseous muscles


Posterior (dorsal) view
Ulna
Radius
Radial artery
Abductor digiti minimi muscle
Abductor pollicis brevis muscle
Dorsal interosseous muscles (bipennate)
4
3
2
1
Anterior (palmar) view
Ulna
Radius
Palmar interosseous muscles (unipennate)
Deep transverse metacarpal ligaments
1
2
3
Tendinous slips to extensor expansions (hoods)

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
INTRINSICS					
Lumbricals 1 & 2	FDP tendons (radial 2)	Radial lateral bands	Median	Extend PIP, flex MCP	Only muscles in body to insert on their own antagonist (FDP). Palmar to deep transverse MC ligaments.
Lumbricals 3 & 4	FDP tendons (medial 3)	Radial lateral bands	Ulnar	Extend PIP, flex MCP	
Interosseous: dorsal (DIO)	Adjacent metacarpals	Proximal phalanx and extensor expansion (lateral bands)	Ulnar	Digit abduction MCP flexion	DAB: Dorsal ABduct Bipennate: each belly has separate insertion
Interosseous: palmar (PIO)	Adjacent metacarpals	Extensor expansion (lateral bands)	Ulnar	Digit adduction	PAD: Palmar ADduct Unipennate


Carpal tunnel release
Thenar compartment
Dorsal incision 2
Adductor compartment
Hypothenar compartment
Dorsal incision 1
Palmar interosseous compartments
Dorsal interosseous compartments


Transverse carpal ligament
Carpal tunnel release
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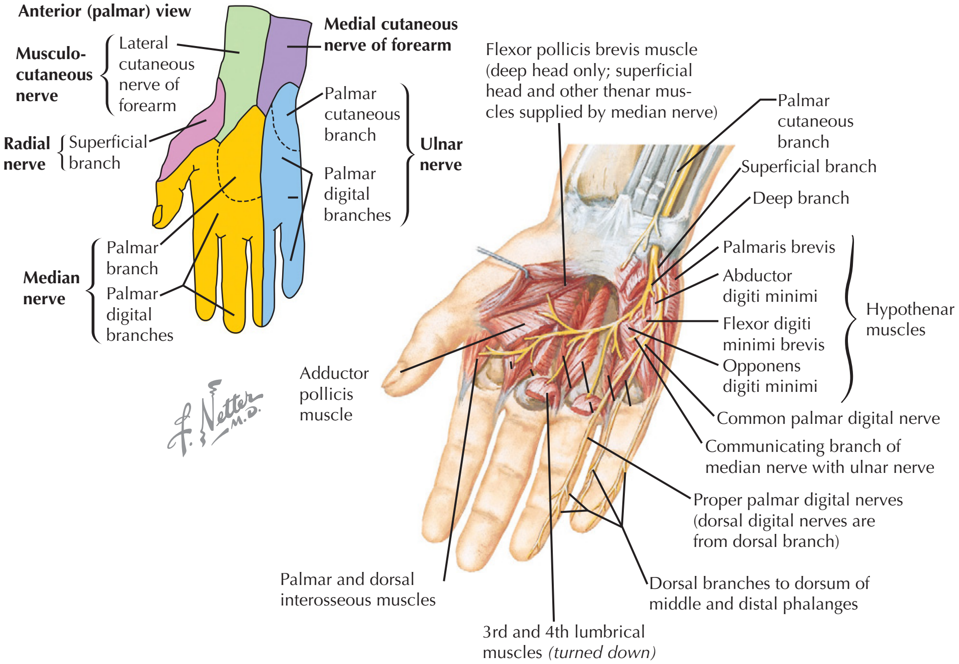
CONTENTS	COMPARTMENT
COMPARTMENTS (10)	
Thenar	Abductor pollicis brevis, flexor pollicis brevis, opponens pollicis
Hypothenar	Abductor digiti minimi, flexor digiti minimi brevis, opponens digiti minimi
Adductor	Adductor pollicis
Palmar interosseous (3)	Palmar interosseous muscles
Dorsal interosseous (4)	Dorsal interosseous muscles
FASCIOTOMIES	
Incisions	3 incisions (2 dorsal and 1 carpal tunnel release) can release all compartments.
Dorsal (1)	Over 2nd metacarpal, dissect on both sides: release radial 2 interosseous (2 dorsal, 1 palmar)
Dorsal (2)	Over 4th metacarpal, dissect on both sides: release ulnar 4 interosseous (2 dorsal, 2 palmar)
Medial	Release transverse carpal ligament, then thenar, hypothenar, & adductor compartments

Cutaneous innervation of the hand


Anterior (palmar) view
Musculo-cutaneous nerve
Lateral cutaneous nerve of forearm
Radial nerve
Superficial branch
Median nerve
Palmar branch
Palmar digital branches
Medial cutaneous nerve of forearm
Palmar cutaneous branch
Palmar digital branches
Ulnar nerve
Flexor pollicis brevis muscle (deep head only; superficial head and other thenar muscles supplied by median nerve)
Palmar cutaneous branch
Superficial branch
Deep branch
Palmaris brevis
Abductor digiti minimi
Flexor digiti minimi brevis
Opponens digiti minimi
Hypothenar muscles
Common palmar digital nerve
Communicating branch of median nerve with ulnar nerve
Proper palmar digital nerves (dorsal digital nerves are from dorsal branch)
Dorsal branches to dorsum of middle and distal phalanges
3rd and 4th lumbrical muscles (turned down)
Palmar and dorsal interosseous muscles
Adductor pollicis muscle
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BRACHIAL PLEXUS

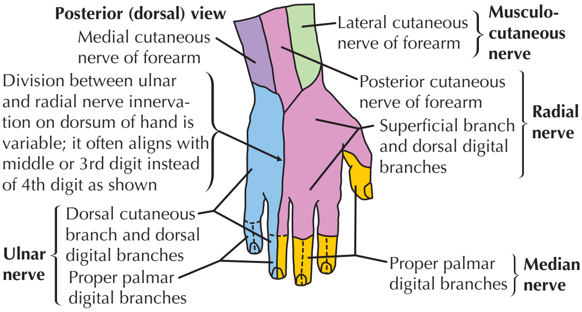
Medial Cord

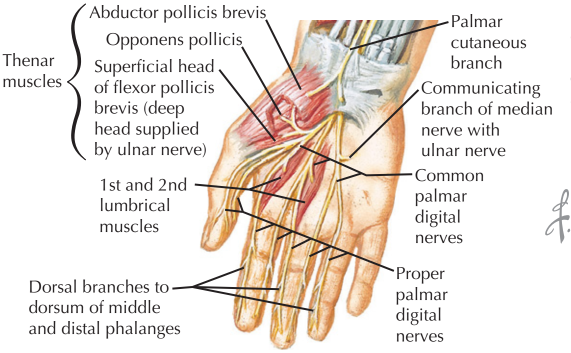
Ulnar (C[7]8-T1): Runs in forearm under FCU, on FDP. **Dorsal cutaneous branch** divides 5cm proximal to wrist. This nerve continues into the dorsal aspect of the ulnar digits as **dorsal digital nerves**. Ulnar nerve enters Guyon's canal, then divides into **superficial** (sensory) and **deep** (motor) branches. The deep branch bends around the hook of the hamate and runs with the deep arterial arch. The superficial branch continues into the palmar aspect of the fingers as the **palmar digital nerves**.

Sensory: Dorsal ulnar hand: via **dorsal cutaneous branch**
Dorsal small & ring fingers: via **dorsal digital branches**
Ulnar proximal palm: via **palmar cutaneous branch**
Ulnar distal palm: via **common palmar digital branches**
Palmar small & ring fingers: via **proper palmar digital branches**

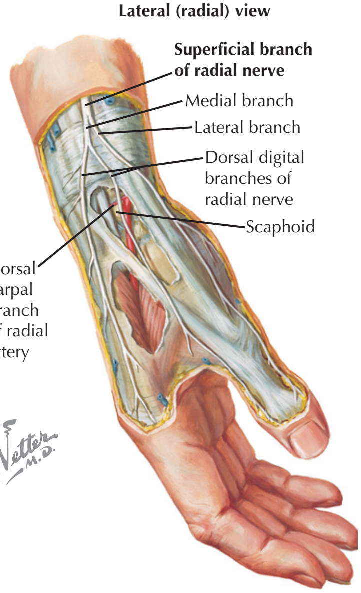
Motor: **Superficial (sensory) branch**
- ◦ Palmaris brevis—only muscle innervated by this branch

Deep (motor) branch: travels with deep arterial arch
- Hypothenar compartment
  - Abductor digiti minimi (ADM)
  - Flexor digiti minimi brevis (FDMB)
  - Opponens digiti minimi (ODM)
- Adductor compartment
  - Adductor pollicis
- Intrinsic muscles
  - Lumbricals (ulnar two [3,4])
  - Dorsal interossei (DIO)
  - Palmar (volar) interossei (VIO)
- Thenar compartment
  - Flexor pollicis brevis (FPB)—deep head only


Posterior (dorsal) view
Medial cutaneous nerve of forearm
Division between ulnar and radial nerve innervation on dorsum of hand is variable; it often aligns with middle or 3rd digit instead of 4th digit as shown
Ulnar nerve
Dorsal cutaneous branch and dorsal digital branches
Proper palmar digital branches
Lateral cutaneous nerve of forearm
Musculocutaneous nerve
Posterior cutaneous nerve of forearm
Superficial branch and dorsal digital branches
Radial nerve
Proper palmar digital branches
Median nerve


Thenar muscles
Abductor pollicis brevis
Opponens pollicis
Superficial head of flexor pollicis brevis (deep head supplied by ulnar nerve)
1st and 2nd lumbrical muscles
Dorsal branches to dorsum of middle and distal phalanges
Palmar cutaneous branch
Communicating branch of median nerve with ulnar nerve
Common palmar digital nerves
Proper palmar digital nerves

Wrist and Hand: Superficial Radial Dissection


Lateral (radial) view
Superficial branch of radial nerve
Medial branch
Lateral branch
Dorsal digital branches of radial nerve
Scaphoid
Dorsal carpal branch of radial artery
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BRACHIAL PLEXUS

Medial and Lateral Cords

Median (C[5]8-T1): Runs in forearm on FDP. **Palmar cutaneous branch** branches proximal to the carpal tunnel. The median nerve enters the carpal tunnel. The **motor recurrent branch** exits distal to transverse carpal ligament (TCL) and supplies the thenar muscles. Anatomic variants include exit through (at risk in carpal tunnel release) or under the TCL. The remainder of the nerve is sensory and supplies the palmar radial 3½ digits.

Sensory: Palm of hand: via **palmar cutaneous branch**
Volar thumb, IF, MF, radial RF: via **palmar digital branches**
Dorsal distal thumb, IF, MF, radial RF: via **proper palmar digital branch**

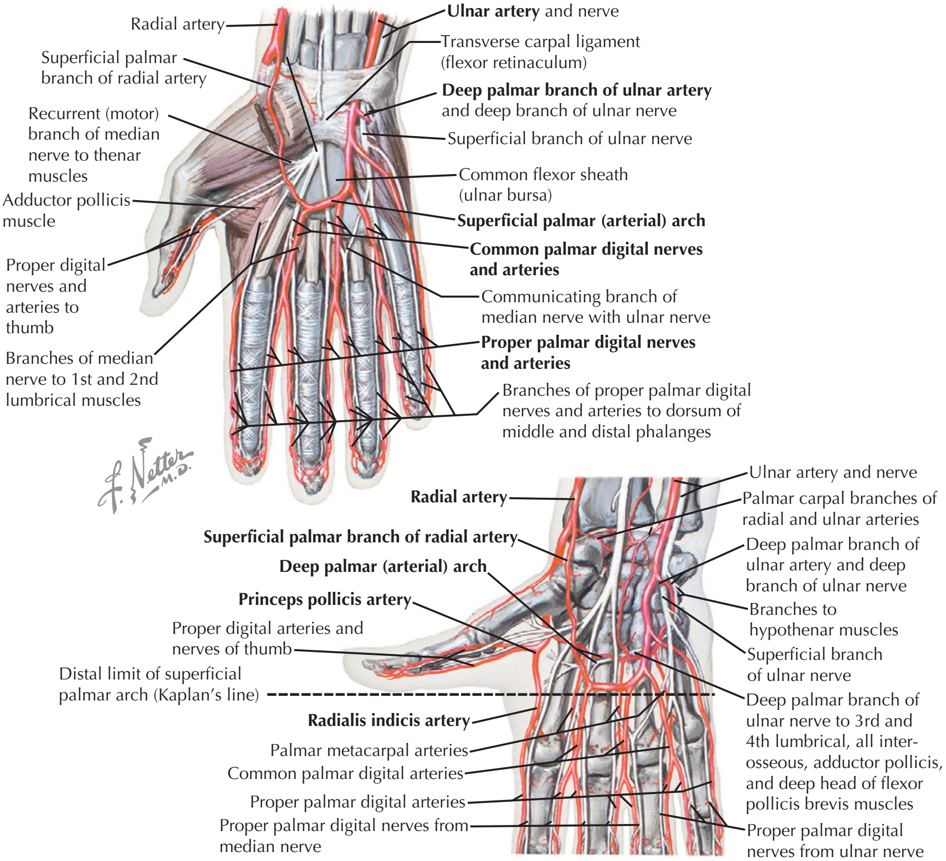
Motor: **Motor (recurrent) branch**
- Thenar compartment
  - Abductor pollicis brevis (APB)
  - Opponens pollicis
  - Flexor pollicis brevis (FPB)—superficial head only
- Intrinsic muscles
  - Lumbricals (radial two [1,2])

Posterior Cord

Radial (C5-T1): Superficial branch runs under brachioradialis to wrist, then bifurcates in medial & lateral branches that supply the dorsal hand & thumb web space. They continue as **dorsal digital branches** to the dorsal fingers.

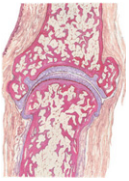
Sensory: Dorsal radial hand: via **superficial branch**
Dorsal proximal thumb, IF, MF, radial RF: via **dorsal digital branches**

Motor: None (in hand)

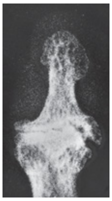

Radial artery
Superficial palmar branch of radial artery
Recurrent (motor) branch of median nerve to thenar muscles
Adductor pollicis muscle
Proper digital nerves and arteries to thumb
Branches of median nerve to 1st and 2nd lumbrical muscles
Ulnar artery and nerve
Transverse carpal ligament (flexor retinaculum)
Deep palmar branch of ulnar artery and deep branch of ulnar nerve
Superficial branch of ulnar nerve
Common flexor sheath (ulnar bursa)
Superficial palmar (arterial) arch
Common palmar digital nerves and arteries
Communicating branch of median nerve with ulnar nerve
Proper palmar digital nerves and arteries
Branches of proper palmar digital nerves and arteries to dorsum of middle and distal phalanges
F. Netter M.D.
Radial artery
Superficial palmar branch of radial artery
Deep palmar (arterial) arch
Princeps pollicis artery
Proper digital arteries and nerves of thumb
Distal limit of superficial palmar arch (Kaplan's line)
Radialis indicis artery
Palmar metacarpal arteries
Common palmar digital arteries
Proper palmar digital arteries
Proper palmar digital nerves from median nerve
Ulnar artery and nerve
Palmar carpal branches of radial and ulnar arteries
Deep palmar branch of ulnar artery and deep branch of ulnar nerve
Branches to hypothenar muscles
Superficial branch of ulnar nerve
Deep palmar branch of ulnar nerve to 3rd and 4th lumbrical, all interosseous, adductor pollicis, and deep head of flexor pollicis brevis muscles
Proper palmar digital nerves from ulnar nerve

COURSE	BRANCHES	COMMENT/SUPPLY
• **Radial artery:** divides at wrist into **superficial branch,** which anastomoses with the superficial palmar arch. The **deep branch** runs thru the bellies of the 1st dorsal interosseous muscle & terminates as the **deep palmar arch.** • **Ulnar artery:** divides at wrist into a **deep branch,** which anastomoses with the deep palmar arch. The **superficial branch** terminates as the **superficial palmar arch.**		
DEEP PALMAR ARCH		
Runs volar to the bases of the metacarpals. It is proximal to the superficial arch.	Princeps pollicis Radialis indicis Proper digital arteries of thumb (2) Palmar metacarpal (3)	Continuation of deep branch of radial artery Supplies radial IF; may branch from deep arch Two terminal branches of bifurcated princeps pollicis Anastomoses with common digital arteries
SUPERFICIAL PALMAR ARCH		
Located at Kaplan's line; distal to the deep arch	Proper palmar digital artery to SF Common palmar digital (3) Proper palmar digital	First branch off arch; supplies ulnar small finger In 2nd-4th web spaces, each bifurcates Runs on radial & ulnar borders of digits
• Superficial arch supplies most of the hand/fingers. It is dominant ⅔ of the time. This arch is complete 80% of the time. • Deep arch supplies the thumb (& radial IF). It is usually the nondominant arch. This arch is complete 98% of the time. • The archs are codominant ⅓ of the time. Allen's test determines if arch is complete (but not which is dominant). • Arteries are volar to the nerves in the palm, but cross to become dorsal to the nerves in the fingers.		

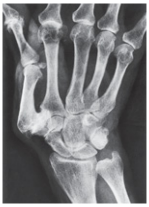
Osteoarthritis



Section through distal interphalangeal joint shows irregular, hyperplastic bony nodules (Heberden's nodes) at articular margins of distal phalanx. Cartilage eroded and joint space narrowed

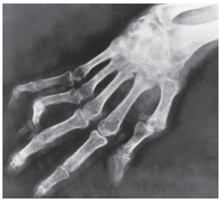


Radiograph of distal interphalangeal joint reveals late-stage degenerative changes. Cartilage destruction and marginal osteophytes (Heberden's nodes)

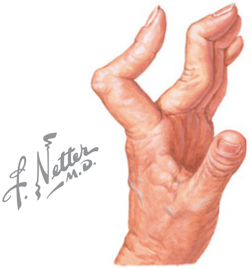


Late-stage degenerative changes in carpometacarpal articulation of thumb

Rheumatoid arthritis



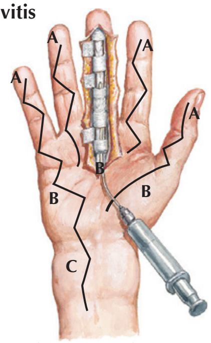
Radiograph shows cartilage thinning at proximal interphalangeal joints, erosion of carpus and wrist joint, osteoporosis, and finger deformities



Boutonniere deformity of index finger with swan-neck deformity of other fingers

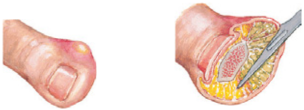
DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
OSTEOARTHRITIS			
• Loss of articular cartilage • Due to wear or posttraumatic • DIPJ #1 (Heberden's nodes) • PIPJ #2 (Bouchard's nodes)	**Hx:** Elderly or hx of injury Pain: worse w/activity **PE:** Nodule/deformity, tenderness, decreased ROM	**XR:** OA findings: joint space loss, osteophytes, sclerosis, subchondral cysts	1. NSAIDs 2. Steroid injection 3. Arthrodesis/fusion 4. Arthroplasty
MUCOUS CYST			
• Ganglion cyst from arthritic joint (DIPJ #1)	**Hx:** Mass near a joint **PE:** Mass, +/− tenderness	**XR:** Joint arthritis	1. Excision of cyst and associated osteophyte
RHEUMATOID ARTHRITIS			
• Autoimmune disease attacks synovium and destroys joints • MCPJ #1 • Multiple deformities develop	**HX:** Pain and stiffness (worse in AM) **PE:** Deformities (ulnar drift, swan neck, boutonniere)	**XR:** Joint destruction **LABS:** RF, ANA, ESR, CBC, uric acid	1. Medical management 2. Synovectomy (1 joint) 3. Tendon transfer/repair 4. Arthrodesis/arthroplasty
SWAN NECK DEFORMITY			
• FDS insertion/volar plate injury • Traumatic or assoc. with RA • Lateral bands subluxate dorsally, hyperextends PIPJ	**Hx:** Injury or RA **PE:** Deformity: flexed DIPJ, injury hyperextended PIPJ	**XR:** Shows bony deformity	1. Early: splint 2. Late: surgical release and reconstruction 3. Arthrodesis
BOUTONNIERE DEFORMITY			
• Central slip (EDC) and triangular ligament injury • Traumatic or assoc. with RA • Lateral bands subluxate volarly, hyperflexes PIPJ	**Hx:** Traumatic injury or RA **PE:** Deformity: flexed PIPJ, + Elson's test (inability to extend the flexed PIPJ)	**XR:** Shows bony deformity	1. Early: splint PIPJ in extension 2. Reconstruct lateral bands and central slip 3. Arthrodesis/arthroplasty

Tenosynovitis



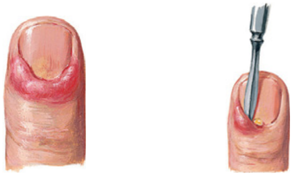
Tenosynovitis of the middle finger. Treated with zigzag volar incision. Tendon sheath opened by reflecting cruciate pulleys. Fine plastic catheter inserted for irrigation. Lines of incision indicated for tendon sheaths of other fingers (A); radial and ulnar bursae (B); and Parona's subtendinous space (C)

Felon



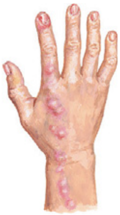
Cross section shows division of septum in finger pulp

Paronychia infection



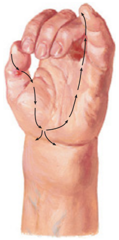
Eponychium elevated from nail surface

Sporotrichosis



Begins as small nodule and spreads to hand, wrist, forearm (even systemically).

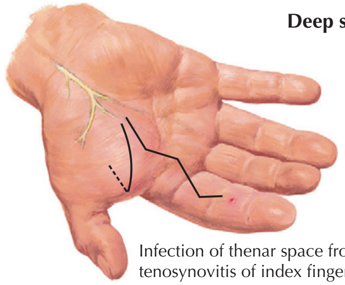
Horseshoe abscess



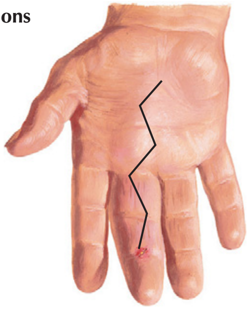
From focus in thumb spreads through radial and ulnar bursae and tendon sheath of little finger, with rupture into Parona's subtendinous space

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
PURULENT FLEXOR TENOSYNOVITIS			
• Tendon sheath infection • Usu. from puncture/bite • May spread proximally into deep spaces or Parona's space (horseshoe abscess)	**Hx:** Pain and swelling **PE:** Kanaval signs (4): 1. Flexed position 2. Fusiform swelling 3. Pain w/passive extension 4. Flexor sheath tenderness	**XR:** Plain films. r/o foreign body, air **LABS:** CBC, ESR, CRP	1. Diagnosis <24hr: IV antibiotics, close observation (I&D if no improvement) 2. Diagnosis >24hr: irrigation and debridement of sheath + IV antibiotics
FELON			
• Deep infection/abscess in pulp of finger • *Staph. aureus* #1	**Hx:** Pain & swelling **PE:** Pointing abscess, edema, erythema, +/− drainage	**XR:** Usually not needed	1. Incise and drain (must release septum in pulp) 2. Antibiotics (IV vs oral)
PARONYCHIA / EPONYCHIA			
• Infection of nail fold • #1 hand infection • Etiology: nail biting, hang nails	**Hx:** Pain & swelling **PE:** Erythema, tenderness, +/− drainage	**XR:** Usually not needed	1. Early: warm soaks 2. I&D and oral antibiotics 3. Partial nail excision
DEEP SPACE INFECTIONS			
• Infection in deep spaces or tissues (e.g., thenar, hypothenar, Parona's [horseshoe])	**Hx:** Pain & swelling **PE:** Edema, erythema, tenderness, fluctuance, +/− drainage	**XR:** Usually normal **MR/CT:** May help if diagnosis is unclear	1. Incise & drain, IV abx 2. Wound care/dressing changes as needed
SPOROTRICHOSIS			
• Fungal *(Sporothrix s.)* infection from plants/roses • Spreads via lymphatics	**Hx:** Rash/discoloration **PE:** Early: single nodule Late: multiple nodules/rash	**XR:** Usually not needed	Potassium iodine solution

Deep space infections

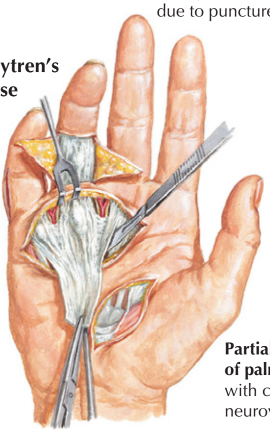


Infection of thenar space from tenosynovitis of index finger due to puncture wound.



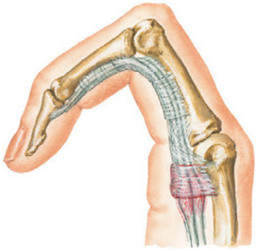
Infection of midpalmar space secondary to tenosynovitis of middle finger. Focus is infected puncture wound at distal crease. Line of incision indicated

Dupuytren's Disease



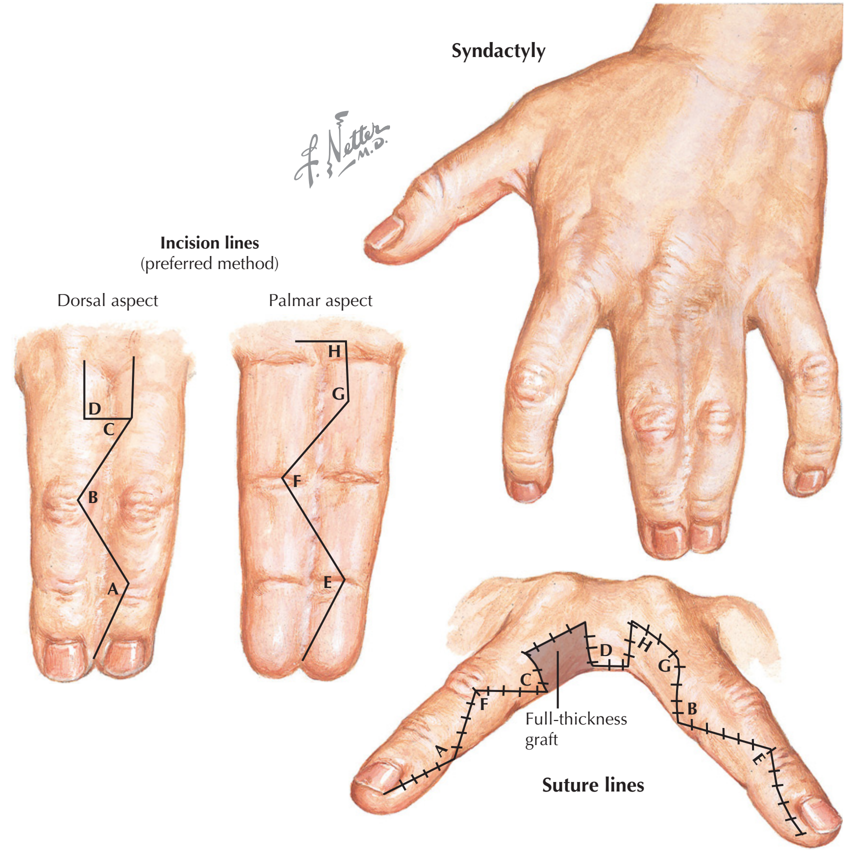
Partial excision of palmar fascia with care to avoid neurovascular bundles.

Stenosing Tenosynovitis (Trigger Finger)



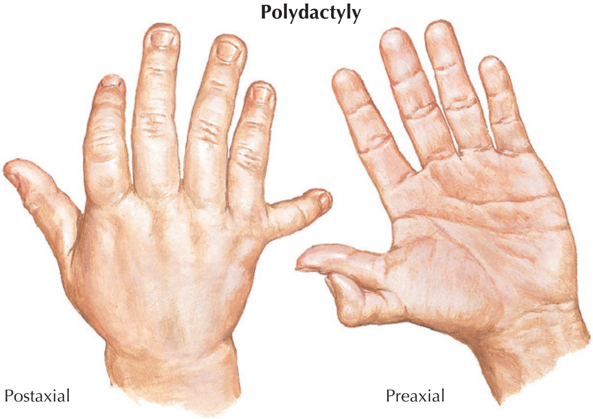
Inflammatory thickening of fibrous sheath (pulley) of flexor tendons with fusiform nodular enlargement of both tendons. Broken line indicates line for incision of lateral aspect of pulley

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
BITES: HUMAN/ANIMAL			
• Usually dominant hand • "Fight bite" = fist to mouth #1 • Bacteria: *Strep., Staph. a.* Human: *Eikenella corr.* Animal: *Pasteurella mult.*	**Hx:** Bite, pain & swelling **PE:** Puncture wound or laceration, edema, +/– drainage, erythema (local or tracking proximally)	**XR:** Hand series: rule out foreign body (e.g., tooth) or air in tissues/joint **LABS:** CBC, ESR, CRP	1. Td & rabies prophylaxis if indicated 2. I&D, wound care 3. IV antibiotics (ampicillin/sulbactam)
STENOSING TENOSYNOVITIS (TRIGGER FINGER)			
• Tight/thickened A1 pulley entraps flexor tendon • Associated with DM, RA, age • Congenital form in pediatrics	**Hx:** 40+, pain, snapping or locking (esp. in AM) **PE:** Tender flexor sheath, snapping with flex./ext.	**XR:** Usually normal **MR:** Not needed, PE is diagnostic	1. Splint, occupational rx 2. Corticosteroid injection into tendon sheath 3. A1 pulley release
DUPUYTREN'S DISEASE			
• Contracture of palmar fascia • Myofibroblasts create thick cords of type III collagen • Associated with northern Europeans (AD), DM, EtOH	**Hx:** Usually male, 40+, c/o hand mass **PE:** Nodule in palm, +/– contracture of MCPJ or PIPJ	**XR:** Usually normal **MR:** Not needed if diagnosis is clear. May be useful if etiology of mass is unclear.	1. Early (mass, no contracture): reassurance 2. Late (contracture): surgical excision of cords
RETINACULAR CYST			
• Ganglion-type cyst of the flexor tendon sheath • Most common hand mass	**Hx:** Small volar mass **PE:** Firm, "pea"-size nodule, does not move w/tendon	**XR:** Usually normal **MR:** Not needed	1. Aspiration/puncture 2. Surgical excision if recurrent

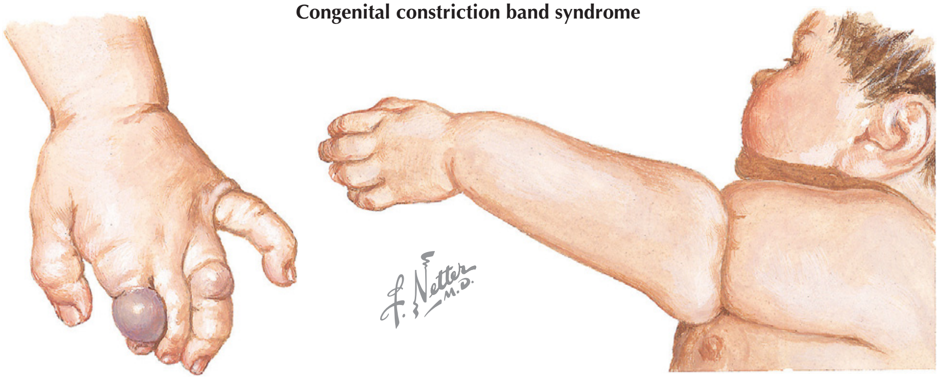


DESCRIPTION	EVALUATION	TREATMENT
SYNDACTYLY		
• Failure of differentiation of finger tissue • Most common congenital hand anomaly • Complete (to finger tip) vs incomplete • Simple (soft tissue) vs complex (bone)	**Hx:** Fingers are connected **PE:** Fingers are connected either to tip or incompletely down the finger **XR:** Will determine if bones are fused (complex)	1. Should wait approximately 1yr, then surgically separate fingers 2. Careful incision planning and skin grafts improve results
CAMPTODACTYLY		
• Congenital finger flexion anomaly • Usually PIPJ of small finger • Type 1 (infants), type 2 (adolescents) • Etiology: abnormal lumbrical or FDS insertion	**Hx:** Finger flexed. Noticed at birth or during adolescent growth **PE:** Inability to fully extend joint **XR:** Shows flexion, bones typically normal	1. Nonoperative: stretching, splint 2. Functionally debilitating contracture: surgical release/tendon transfer
CLINODACTYLY		
• Deviation of finger in coronal plane • Radial deviation of small finger #1 • Etio: delta-shaped middle phalanx	**Hx/PE:** Deviation of finger, cosmetic and functional complaints **XR:** Shows delta-shaped middle phalanx	1. Mild: no treatment 2. Functional deficit: surgical correction/realignment osteotomy

Polydactyly

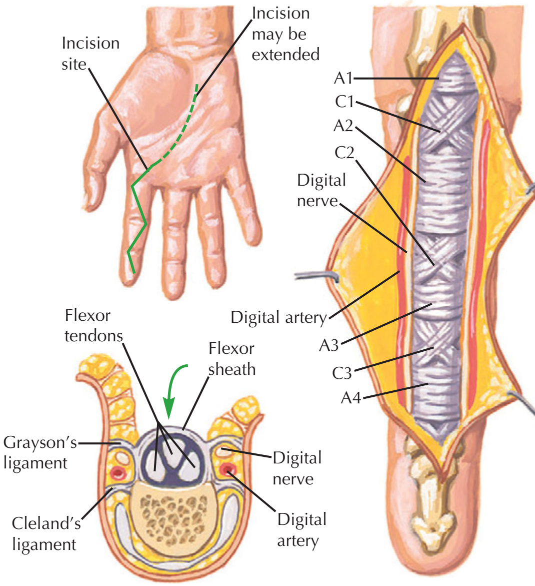


Congenital constriction band syndrome

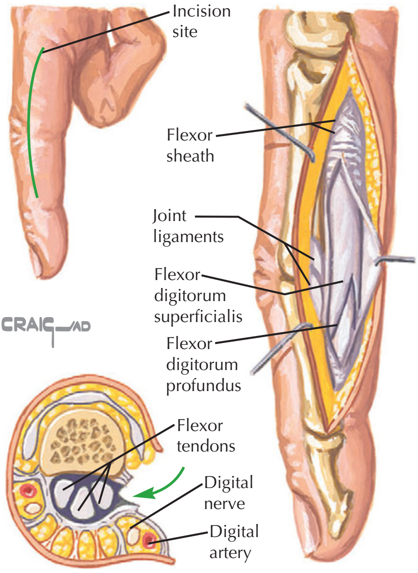


DESCRIPTION	EVALUATION	TREATMENT
	DUPLICATE THUMB (PREAXIAL POLYDACTYLY)	
• An extra thumb or portion thereof • Wassel classification (7 types): Type 4 is most common • Autosomal dominant or sporadic • Associated with some syndromes	**Hx/PE:** Extra thumb or portion of thumb **XR:** Will show bifid or extra phalanges depending on which type of duplication	1. Surgical reconstruction to obtain stable thumb. Generally, retain ulnar thumb/ structures & reconstruct radial side (e.g., type 4)
	THUMB HYPOPLASIA	
• Partial or complete absence of thumb • Blauth classification: Types I– V • Treatment based on presence of CMC joint • Associated with some syndromes	**Hx/PE:** Small to completely absent thumb **XR:** Range of small, shortened, or absent bones (phalanges, metacarpal, trapezium). Evaluate for presence of the CMC joint	1. Type I: Small thumb: no treatment 2. Types II-IIIA: Reconstruction 3. Types IIIB-V (no CMCJ): amputation & pollicization
	CONSTRICTION BAND SYNDROME	
• Constrictive bands lead to digit necrosis or diminished growth/ development. • Nonhereditary	**Hx/PE:** Short/truncated fingers with bands at level of diminished growth **XR:** Small, shortened, or absent phalanges	1. Complete amputations if needed 2. Release/excise bands, Z-plasty as needed for skin coverage

Volar approach to finger


Incision site
Incision may be extended
A1
C1
A2
C2
Digital nerve
Digital artery
A3
C3
A4
Flexor tendons
Flexor sheath
Grayson's ligament
Cleland's ligament
Digital nerve
Digital artery

Midlateral approach to finger


Incision site
Flexor sheath
Joint ligaments
Flexor digitorum superficialis
Flexor digitorum profundus
Flexor tendons
Digital nerve
Digital artery

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
FINGER: VOLAR APPROACH			
• Flexor tendons (repair/explore) • Digital nerves • Soft tissue releases • Infection drainage	No planes	• Digital artery • Digital nerve • Flexor tendon	• Make a "zigzag" incision connecting finger creases • Neurovascular bundle is lateral to the tendon sheath.
FINGER: MID-LATERAL APPROACH			
• Phalangeal fractures	No planes	• Digital nerve • Digital artery	• Soft tissues are thin; capsule can be incised if care is not taken.

CHAPTER 7
Pelvis

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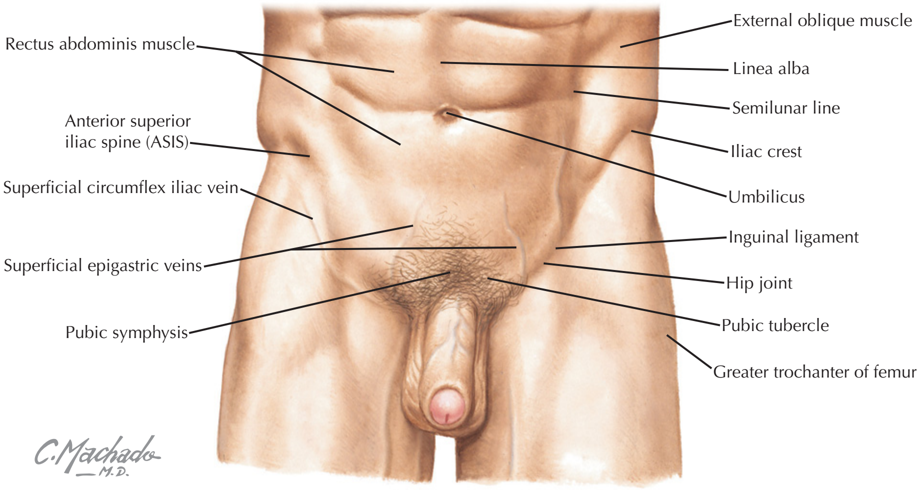
Rectus abdominis muscle
Anterior superior iliac spine (ASIS)
Superficial circumflex iliac vein
Superficial epigastric veins
Pubic symphysis
External oblique muscle
Linea alba
Semilunar line
Iliac crest
Umbilicus
Inguinal ligament
Hip joint
Pubic tubercle
Greater trochanter of femur
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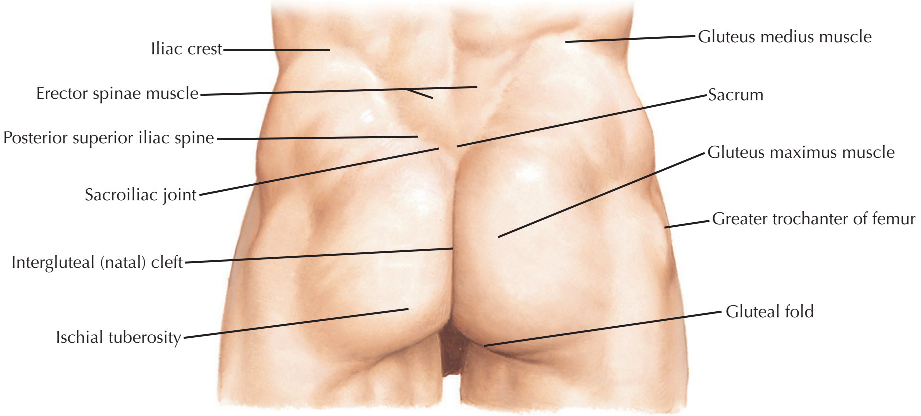
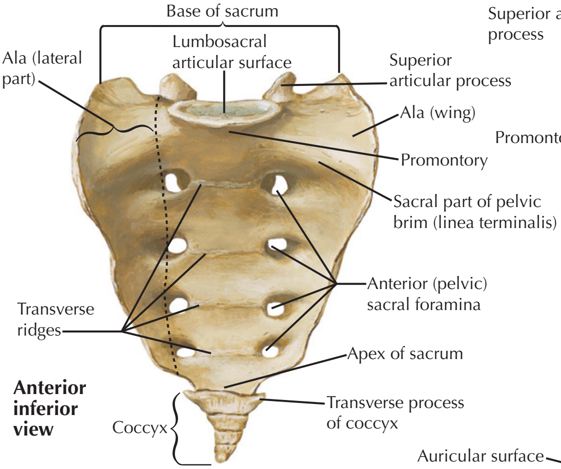
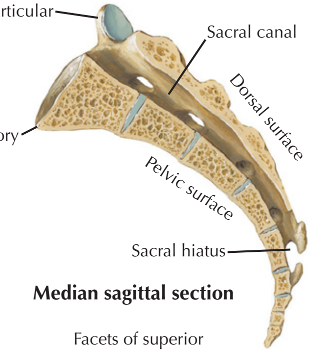

Iliac crest
Erector spinae muscle
Posterior superior iliac spine
Sacroiliac joint
Intergluteal (natal) cleft
Ischial tuberosity
Gluteus medius muscle
Sacrum
Gluteus maximus muscle
Greater trochanter of femur
Gluteal fold

STRUCTURE	CLINICAL APPLICATION
Iliac crest	Site for contusion of lilac crest ("hip pointers") Common site for autologous bone graft harvest
Anterior superior iliac spine	Origin of sartorius muscle. An avulsion fracture can occur here. Lateral femoral cutaneous nerve (LFCN) courses here and can be entrapped. Landmark used for measuring the "Q" angle of the knee
Symphysis pubis	Site of osteitis pubis; uncommon cause of anterior pelvic pain
Inguinal ligament	External iliac artery becomes femoral artery here; femoral pulse can be palpated just inferior to the ligament in the femoral triangle.
Greater trochanter	Tenderness can indicate trochanteric bursitis.
Erector spinae muscles	Overuse and spasm are common causes of lower back pain (LBP).
Posterior superior iliac spine	Site of bone graft harvest in posterior spinal procedures.
Sacroiliac joint	Degeneration of joint can cause lower back pain (LBP).
Ischial tuberosity	Avulsion fracture (hamstring muscles) or bursitis can occur here.

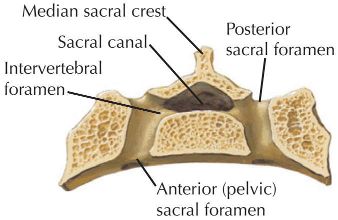

Base of sacrum
Lumbosacral articular surface
Ala (lateral part)
Superior articular process
Ala (wing)
Promontory
Sacral part of pelvic brim (linea terminalis)
Anterior (pelvic) sacral foramina
Transverse ridges
Apex of sacrum
Transverse process of coccyx
Coccyx

Anterior inferior view

Pelvic surface


Superior articular process
Sacral canal
Dorsal surface
Promontory
Pelvic surface
Sacral hiatus

Median sagittal section


Median sacral crest
Sacral canal
Posterior sacral foramen
Intervertebral foramen
Anterior (pelvic) sacral foramen

Coronal section through S1 foramina

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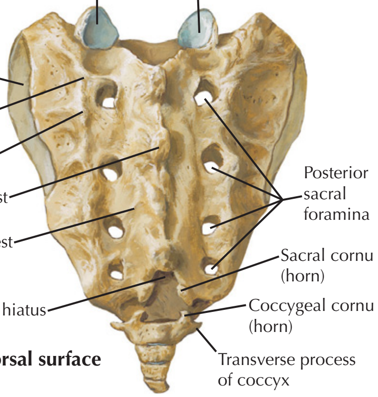
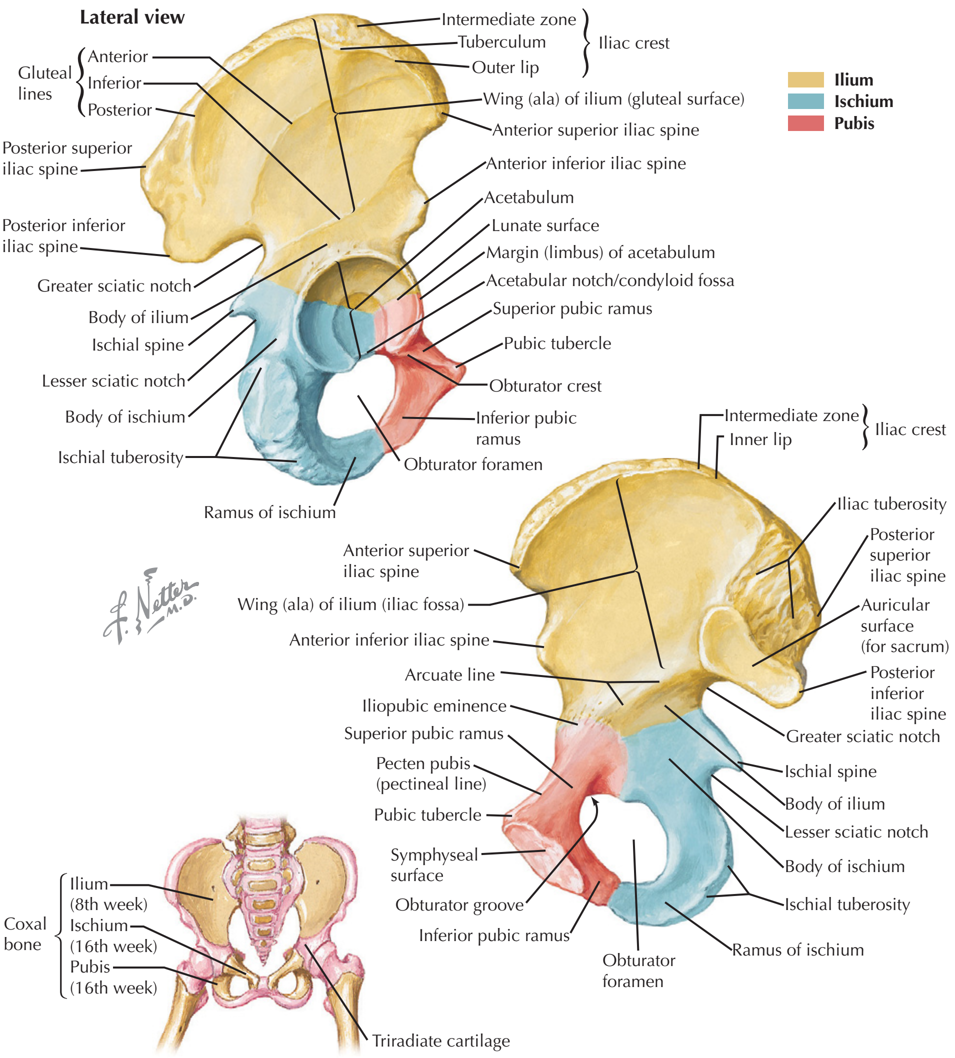

Facets of superior articular processes
Auricular surface
Sacral tuberosity
Lateral sacral crest
Median sacral crest
Intermediate sacral crest
Posterior sacral foramina
Sacral cornu (horn)
Coccygeal cornu (horn)
Sacral hiatus
Transverse process of coccyx

Dorsal surface

Posterior superior view

CHARACTERISTICS	OSSIFY	FUSE	COMMENTS
PELVIS			
• Combination of 3 bones (two innominate bones & sacrum) and 3 joints (two sacroiliac joints & symphysis pubis) • The pelvis has no inherent stability. It requires ligamentous support for its stability. • Two portions of pelvis divided by pelvic brim/iliopectineal line ◦ False (greater) pelvis—above the brim, bordered by the sacral ala and iliac wings ◦ True (lesser) pelvis—below the brim, bordered by the ischium and pubis			
SACRUM			
• 5 vertebra are fused	**Primary**		• Transmits weight from spine to pelvis
• 4 pairs of foramina (left and right)	Body 8wk (fetal)	2-8yr	• Nerves exit through the sacral foramina (anterior & posterior)
• Ala (wing) expands laterally	Arches	2-8yr	• Ala is common site for sacral fractures
• Sacral canal opens to hiatus distally	Costal elements	2-8yr	• Sacral canal narrows distally before opening to sacral hiatus
• Kyphotic (approx. 25°), the apex is at S3	**Secondary** 11-14yr	20yr	• Segments fuse to each other at puberty
COCCYX			
• 4 vertebrae are fused	Primary arch 7-8wk (fetal)	1-2yr	• Is attached to gluteus maximus and coccygeal m.
• Lack features of typical vertebrae	Body	7-10yr	• Common site for "tailbone" fracture


Lateral view
Intermediate zone
Tuberculum
Outer lip
Iliac crest
Gluteal lines
Anterior
Inferior
Posterior
Wing (ala) of ilium (gluteal surface)
Anterior superior iliac spine
Posterior superior iliac spine
Anterior inferior iliac spine
Acetabulum
Lunate surface
Posterior inferior iliac spine
Margin (limbus) of acetabulum
Acetabular notch/condyloid fossa
Greater sciatic notch
Superior pubic ramus
Body of ilium
Ischial spine
Pubic tubercle
Lesser sciatic notch
Obturator crest
Body of ischium
Inferior pubic ramus
Ischial tuberosity
Obturator foramen
Ramus of ischium
Ilium
Ischium
Pubis
Intermediate zone
Inner lip
Iliac crest
Iliac tuberosity
Anterior superior iliac spine
Posterior superior iliac spine
Wing (ala) of ilium (iliac fossa)
Auricular surface (for sacrum)
Anterior inferior iliac spine
Arcuate line
Posterior inferior iliac spine
Iliopubic eminence
Greater sciatic notch
Superior pubic ramus
Pecten pubis (pectineal line)
Ischial spine
Body of ilium
Pubic tubercle
Lesser sciatic notch
Symphyseal surface
Body of ischium
Obturator groove
Ischial tuberosity
Inferior pubic ramus
Ramus of ischium
Obturator foramen
Coxal bone
Ilium (8th week)
Ischium (16th week)
Pubis (16th week)
Triradiate cartilage
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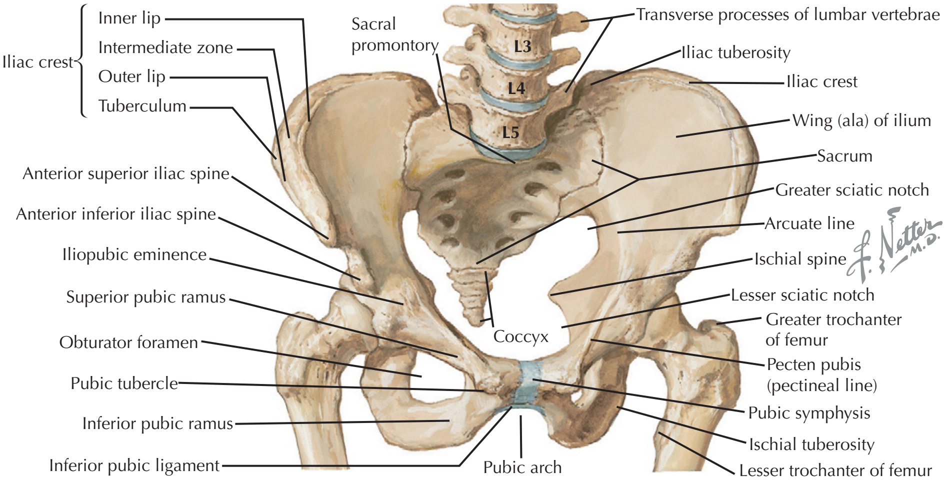
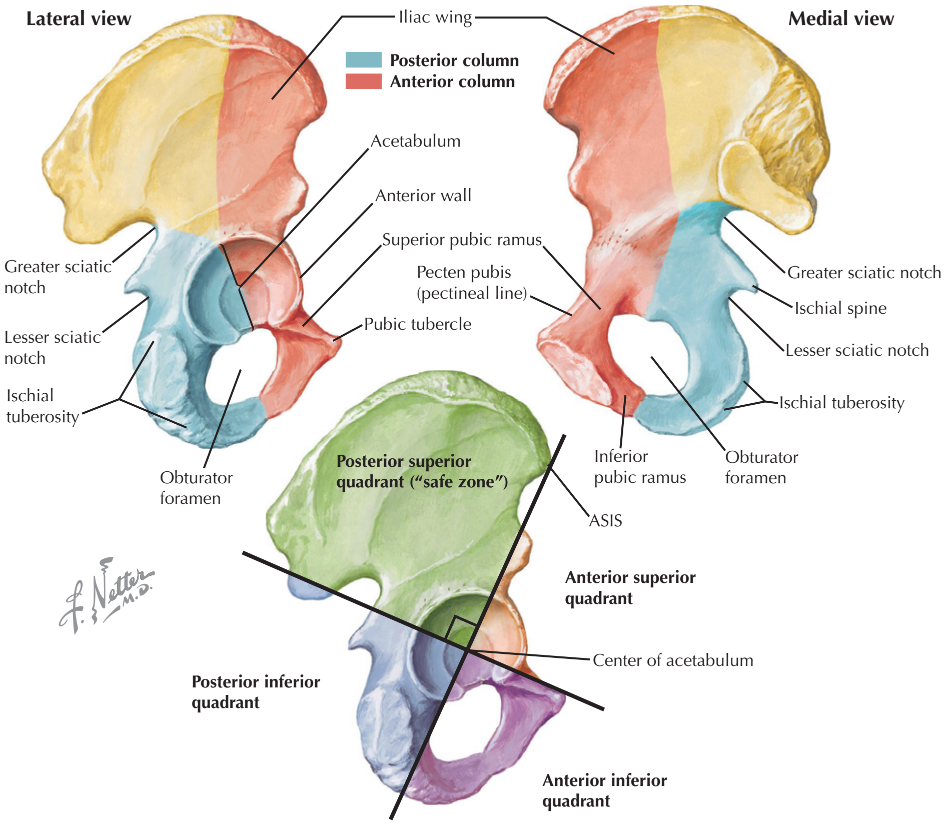
CHARACTERISTICS	OSSIFY		FUSE		COMMENTS
		INNOMINATE BONE			
• 3 bones (ilium, ischium, pubis) fuse to become one bone at triradiate cartilage in acetabulum • Ilium: body, ala (wing) • Pubis: inferior & superior rami • Ischium: body & tuberosity • Acetabulum: "socket" of hip joint, has 2 walls (anterior & posterior) & notch/condyloid fossa inferiorly. Articular cartilage is horseshoe shaped	**Primary** (one in each body)	2-6mo	to acetabulum 15yr		• Iliac crest is common site for both tricortical and cancellous bone graft harvest • Contusion to iliac crest known as "hip pointer" • Iliac crest ossification used to determine skeletal maturity (Risser stage) • Multiple iliac spines serve as anatomic landmarks & muscle insertion sites (ASIS, AIIS, PSIS, PIIS) • Acetabulum: 45° oblique orientation, 15° anteverted
	Secondary Iliac crest Triradiate Ischial tuberosity AIIS Pubis	15yr	All fuse	20yr	


Iliac crest
Inner lip
Intermediate zone
Outer lip
Tuberculum
Sacral promontory
L3
L4
L5
Transverse processes of lumbar vertebrae
Iliac tuberosity
Iliac crest
Wing (ala) of ilium
Sacrum
Greater sciatic notch
Arcuate line
Ischial spine
Lesser sciatic notch
Greater trochanter of femur
Pecten pubis (pectineal line)
Pubic symphysis
Ischial tuberosity
Lesser trochanter of femur
Anterior superior iliac spine
Anterior inferior iliac spine
Iliopubic eminence
Superior pubic ramus
Obturator foramen
Pubic tubercle
Inferior pubic ramus
Inferior pubic ligament
Coccyx
Pubic arch

STRUCTURE	ATTACHMENTS/RELATED STRUCTURES	COMMENT
LANDMARKS AND OTHER STRUCTURES OF THE PELVIS		
Anterior superior iliac spine (ASIS)	Sartorius Inguinal ligament Transverse & int. oblique abdominal m.	• LFCN crosses the ASIS & can be compressed there • Sartorius can avulse from it (avulsion fx) • Landmark to measure Q angle of the knee
Anterior inferior iliac spine (AIIS)	Rectus femoris Tensor fasciae latae Iliofemoral ligament (hip capsule)	• Rectus femoris can avulse from it (avulsion fx)
Posterior superior iliac spine (PSIS)	Posterior SI ligaments Marked by skin dimple	• Excellent bone graft site
Arcuate line	Pectineus	• Aka pectineal line. Strong, weight-bearing region
Gluteal lines	3 lines: anterior, inferior, posterior	• Separate origins of gluteal muscles
Gtr. trochanter	SEE ORIGINS/INSERTIONS	• Tender with trochanteric bursitis
Lesser trochanter	Iliacus/psoas muscle	• Tendon can snap over trochanter ("snapping hip")
Ischial tuberosity	SEE ORIGINS/INSERTIONS Sacrotuberous ligaments	• Excessive friction = bursitis (weaver's bottom) • Hamstrings can avulse (avulsion fx)
Ischial spine	Coccygeus & levator ani attach Sacrospinous ligaments	
Lesser sciatic foramen	Short external rotators exit: Obturator externus Obturator internus	• Obturator internus is landmark to posterior column • Obt. externus not seen in posterior approach
Greater sciatic foramen	Structures that exit: 1. Superior gluteal nerve 2. Superior gluteal artery 3. Piriformis muscle 4. **P**udendal nerve 5. Inferior pudendal artery 6. Nerve to the **O**bturator internus 7. **P**osterior Cutaneous nerve of thigh 8. **S**ciatic nerve 9. **I**nferior gluteal nerve 10. Inferior gluteal artery 11. Nerve to **Q**uadratus femoris	• Piriformis muscle is the reference point • Superior gluteal nerve and artery exit superior to the piriformis • **POP'S IQ** is a mnemonic for the nerves (structures) that exit inferior to the piriformis (medial to lateral) (see page 243) • Sciatic nerve (especially peroneal division) may exit pelvis above or through the piriformis as an anatomic variation


Lateral view
Iliac wing
Medial view
Posterior column
Anterior column
Acetabulum
Anterior wall
Superior pubic ramus
Pecten pubis (pectineal line)
Pubic tubercle
Greater sciatic notch
Lesser sciatic notch
Ischial tuberosity
Obturator foramen
Greater sciatic notch
Ischial spine
Lesser sciatic notch
Ischial tuberosity
Inferior pubic ramus
Obturator foramen
ASIS
Posterior superior quadrant ("safe zone")
Anterior superior quadrant
Center of acetabulum
Posterior inferior quadrant
Anterior inferior quadrant
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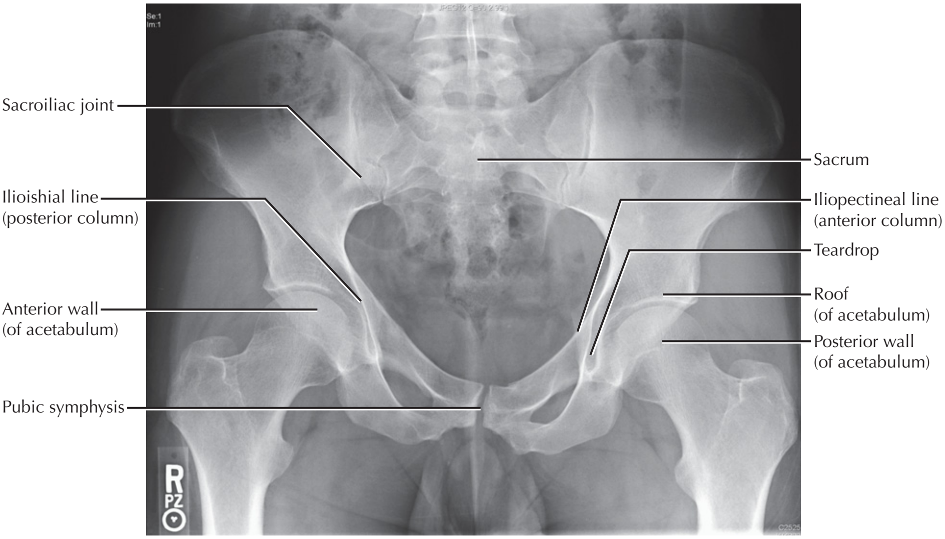
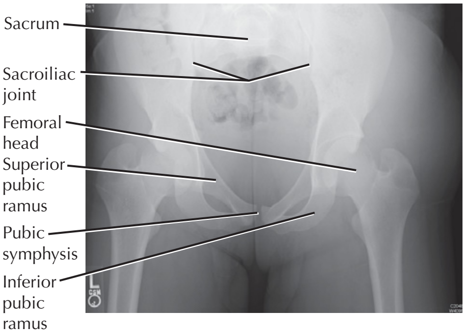
STRUCTURE	RELATED STRUCTURES	COMMENT
ACETABULAR COLUMNS		
Anterior (iliopubic)	1. Superior pubic ramus 2. Anterior acetabular wall 3. Anterior iliac wing 4. Pelvic brim	Involved in several different fracture patterns
Posterior (ilioischial)	1. Ischial tuberosity 2. Posterior acetabular wall 3. Greater & lesser sciatic notches	Involved in several different fracture patterns
ACETABULAR ZONES		
Zones defined by 2 lines: 1. ASIS to center of acetabulum, 2. perpendicular to line 1 Structures can be injured when screws are placed in these zones (e.g., acetabular cups)		
Anterior superior	External iliac artery & vein	Do not put screws in this zone
Anterior inferior	Obturator nerve, artery, vein	Do not put screws in this zone
Posterior superior	Sciatic nerve Superior gluteal nerve, artery, vein	This is the safe zone
Posterior inferior	Sciatic nerve Inferior gluteal nerve, artery, vein Internal pudendal nerve, artery, vein	This is a secondary safe zone. Safe screw placement can be achieved with care if necessary.

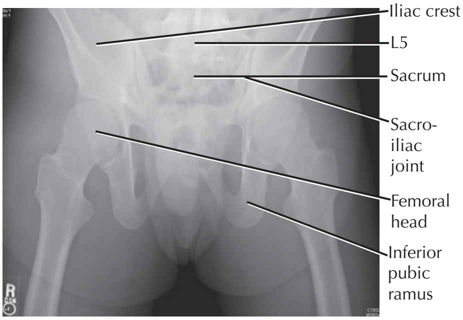
Radiograph, AP pelvis


Sacroiliac joint
Ilioishial line
(posterior column)
Anterior wall
(of acetabulum)
Pubic symphysis
Sacrum
Iliopectineal line
(anterior column)
Teardrop
Roof
(of acetabulum)
Posterior wall
(of acetabulum)
R

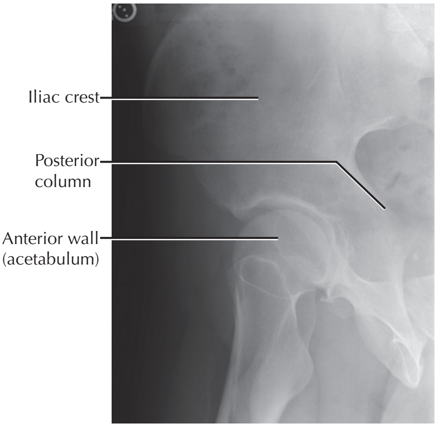
RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
AP (anteroposterior)	AP, IR feet 15°, beam directed at midpelvis	6 radiographic lines: 1. Iliopectineal (ant. column) 2. Ilioischial (post. column) 3. Radiographic "teardrop" 4. Acetabular roof ("dome") 5. Ant. acetabulum rim/wall 6. Post. acetabulum rim/wall	Screening for fractures (sacral, pelvic acetabular, proximal femur), use ATLS protocol; dysplasia, degenerative joint disease/arthritis
Pelvic inlet view	AP, beam 45° caudal	Sacroiliac joints, pelvic brim/ pubic rami, sacrum	Pelvic ring fractures: shows posterior displacement or symphysis widening
Pelvic outlet view	AP, beam 45° cephalad	Iliac crest, symphysis pubis, sacral foramina	Pelvic ring fractures: shows superior displacement of hemipelvis
Oblique/Judet views	Beam at affected hip:		
Obturator oblique	Elevate affected hip 45°	Obturator foramen	Acetabulum fx: anterior column, posterior wall
Iliac oblique	Elevate unaffected hip 45°	Iliac crest, sciatic notches	Acetabulum fx: posterior column, anterior wall
		OTHER STUDIES	
CT	Axial, coronal, & sagittal	Articular congruity, fx fragments	Fractures, especially sacrum & acetabulum
MRI	Sequence protocols	Soft tissues: muscles, cartilage	Labral tears, tumors, stress fx
Bone scan		All bones evaluated	Tumors, infection


Inlet view

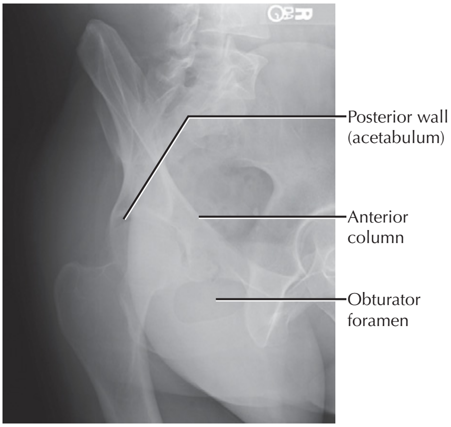
Sacrum
Sacroiliac joint
Femoral head
Superior pubic ramus
Pubic symphysis
Inferior pubic ramus
L


Outlet view

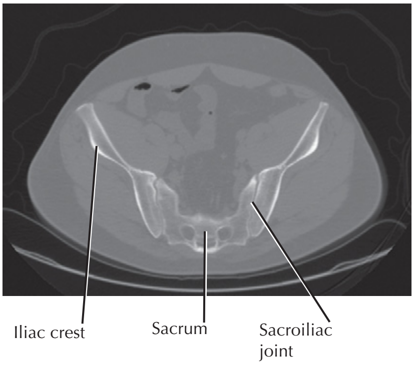
Iliac crest
L5
Sacrum
Sacro-iliac joint
Femoral head
Inferior pubic ramus
R


Iliac oblique (Judet)

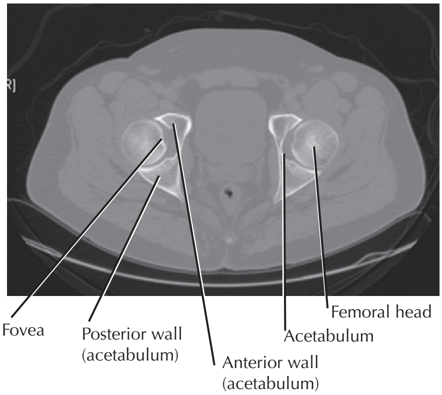
Iliac crest
Posterior column
Anterior wall (acetabulum)


Obturator oblique (Judet)

Posterior wall (acetabulum)
Anterior column
Obturator foramen

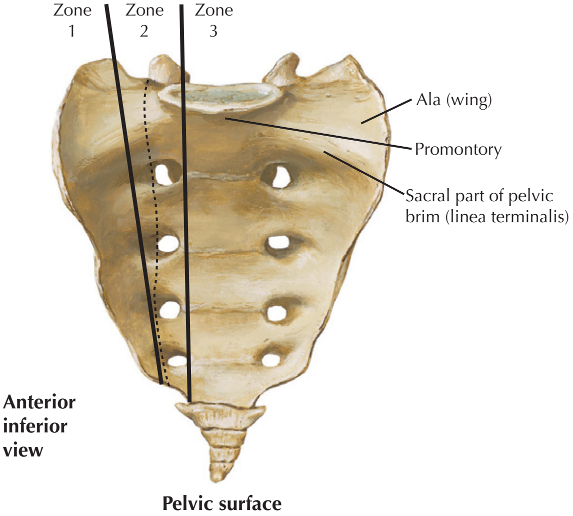

CT pelvis

Iliac crest
Sacrum
Sacroiliac joint

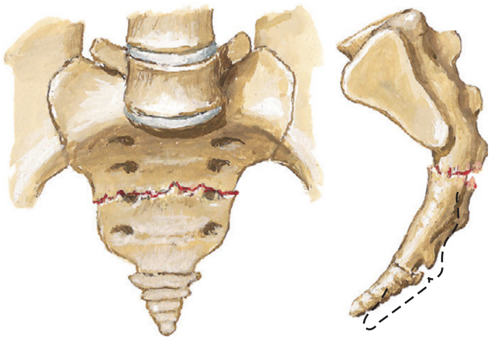

CT pelvis

Fovea
Posterior wall (acetabulum)
Anterior wall (acetabulum)
Acetabulum
Femoral head

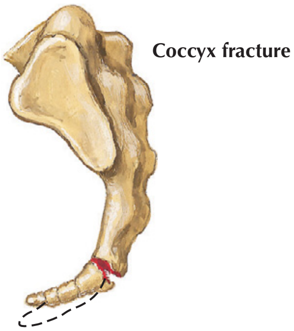
Vertical sacral fracture, Denis classification


Zone 1
Zone 2
Zone 3
Ala (wing)
Promontory
Sacral part of pelvic brim (linea terminalis)
Anterior inferior view
Pelvic surface

Sacral fractures



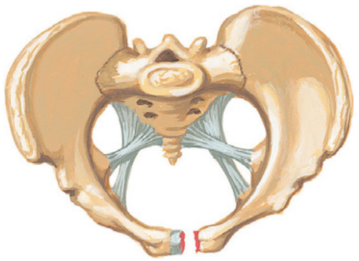
Transverse fracture of the sacrum that is minimally displaced


Coccyx fracture

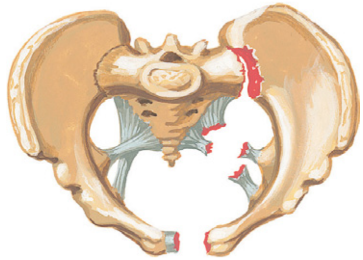
Fracture usually requires no treatment other than care in sitting; inflatable ring helpful. Pain may persist for a long time.

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
SACRAL FRACTURE			
• Mechanism: elderly—fall; young—high energy (e.g., MVA) • Isolated injuries rare, usually assoc. w/pelvis or spine fx • Nerve root injury very common • Plain XR identifies <50% of fractures • Easily missed & difficult to treat, can lead to chronic pain	**Hx:** Trauma (fall or accident), pain +/− neurologic sx **PE:** Palpate spine & sacrum. Complete neuro exam including rectal exam. **XR:** AP pelvis, lateral sacrum **CT:** Necessary for diagnosis & preop planning	**By direction of fracture** • Vertical. Denis: ∘ Zone 1: lateral to foramina ∘ Zone 2: through foramina ∘ Zone 3: medial to foramina • II. Transverse • III. Oblique • Complex: "U" or "H" shape	• Minimally displaced/stable: ∘ Nonoperative • Displaced/unstable: ∘ Closed reduction and percutaneous fixation ∘ Open reduction, internal fixation • Nerve injury: decompression
COMPLICATIONS: Nerve root injury & cauda equina syndrome, esp. zone 3 fractures; nonunion/malunion, chronic pain			

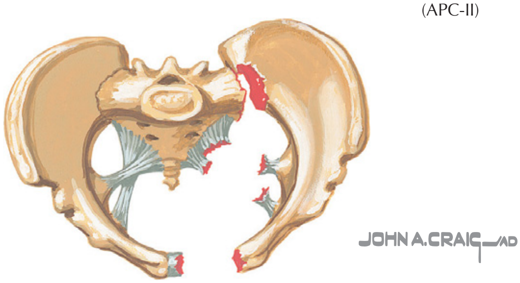
Classification of pelvic fractures (Young and Burgess)



Anteroposterior Compression Type I
(APC-I)



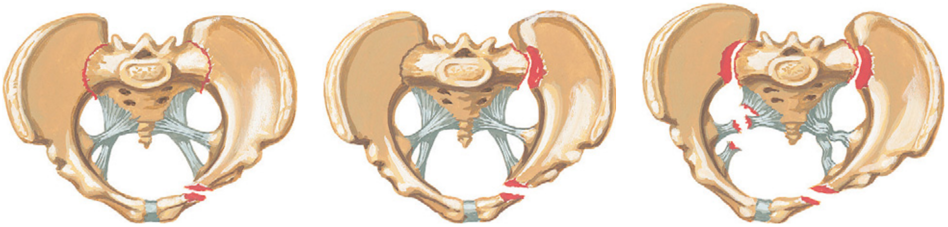
Anteroposterior Compression Type II
(APC-II)



Anteroposterior Compression Type III
(APC-III)

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
PELVIC RING FRACTURE			
• Mechanism: high-energy blunt trauma (e.g., MVA) • Multiple associated injuries: GI, GU, extremity fxs, neurologic, vascular, head (LC) • Very high morbidity, usually due to uncontrolled hemorrhage (venous>arterial bleeding) esp. w/ APC3 ("open book") fxs • Open fracture has higher morbidity and complication rate. • Stability of fx based on ligament disruption (esp. ST, SS, posterior SI) • Avulsion of iliolumbar ligament/L5 transverse process suggests unstable fx • Lateral compression most common ∘ LC1: posterior-directed force ∘ LC2: anterior-directed force	**Hx:** High-energy trauma, pain +/− neurologic sx **PE:** Inspect perineum for open injury. LE may be malrotated. Pelvic "rock." Rectal & vaginal exams for associated injuries. Complete neuro exam incl. rectal tone & bulbocavernosus reflexes. **XR:** AP pelvis, inlet and outlet views are essential. **CT:** Especially useful to define sacral/SIJ injury **AGRAM:** If hemodynamically unstable after pelvic stabilization; consider embolization of artery	Young & Burgess: **AP Compression (APC)** I. <2.5cm pubic diastasis + 1 or 2 pubic rami fractures II. >2.5cm diastasis + anterior SI injury, but vertically stable III. Complete ant. (symphysis) & post. (SIJ) disruption. Unstable **Lateral Compression (LC)** I. Sacral compression + ipsilateral rami fracture II. LC1 + iliac wing fx or post. SIJ injury. Vertically stable III. LC 2 with contralateral APC3 ("windswept" pelvis) **Vertical Shear** SIJ & ST/SS ligament disruption + rami fxs. Vertically unstable	• ATLS protocol. Treat life-threatening injuries • Pelvic hemorrhage: pelvis compression (e.g., sheet) or external fixation to reduce pelvic volume • Diverting colostomy for open injury or any communication w/open bowel • Nonoperative: WBAT for LC1, APC1, ramus fx • Operative for LC2 & 3; APC 2 & 3, vertical stress ∘ Anterior: ORIF of symphysis ∘ Post: 1. ORIF of iliac wing and sacral fractures; 2. SI screws for dislocated SIJ
COMPLICATIONS: Hemorrhage (venous>arterial [internal pudendal a. > superior gluteal a.]), neurologic injuries (L5 root at risk w/SI screws), malunion/nonunion, chronic pain (esp. at SIJ) and functional disability, infection, thromboembolism			

Classification of Pelvic Fractures (Young and Burgess)

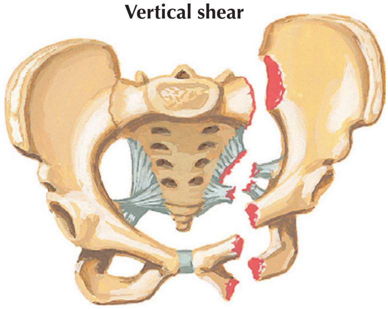


Lateral Compression Type I
(LC-I)

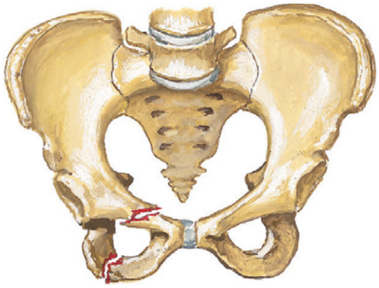
Lateral Compression Type II
(LC-II)

Lateral Compression Type III
(LC-III)

Vertical shear



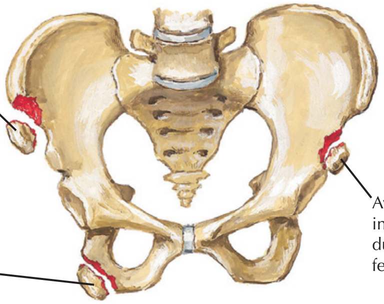
Pelvic rami fractures



Fracture of ipsilateral pubic and ischial ramus requires only symptomatic treatment with short-term bed rest and limited activity with walker- or crutch-assisted ambulation for 4 to 6 weeks.

Fracture of pelvis without disruption of pelvic ring

Avulsions



Avulsion of anterior superior iliac spine due to pull of sartorius muscle

Avulsion of ischial tuberosity due to pull of hamstring muscles

Avulsion of anterior inferior iliac spine due to pull of rectus femoris muscle

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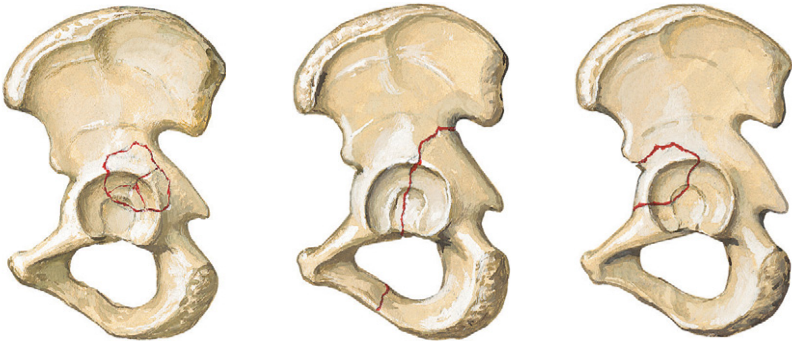
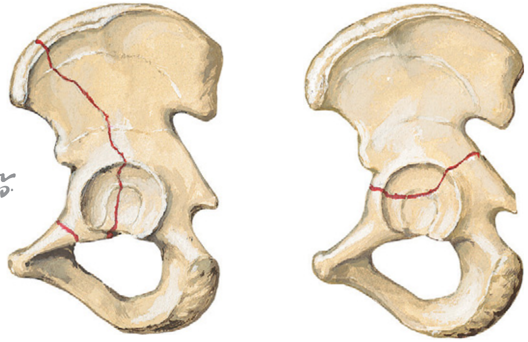
DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
PELVIC FRACTURE—OTHER			
• Mechanism: Low-energy trauma (fall, sports injury, etc) • Stable isolated fractures, pelvic ring not disrupted • Can occur in osteopenic bone	**Hx:** Pain, esp. with WB **PE:** TTP at bony site **XR:** AP, inlet/outlet views **CT:** Often not needed, can determine displacement	**Isolated fxs:** Inferior or superior pubic rami, iliac wing/crest **Avulsions:** ASIS (sartorius), AIIS (rectus femoris), ischial tuberosity (hamstrings)	• Isolated fxs: treat with limited rest, WBAT • Avulsion fx: most treated nonoperatively. Reattach if widely displaced.
COMPLICATIONS: Malunion/nonunion, chronic pain/disability, thromboembolism			

Acetabulum—Elementary Fractures


Fracture of posterior wall

Fracture of posterior column

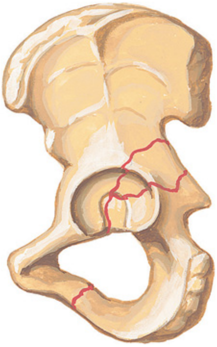
Wedge fracture of anterior wall


Fracture of anterior column

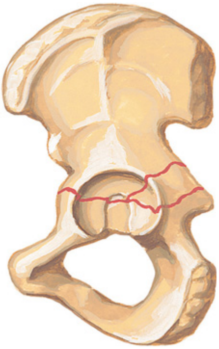
Transverse fracture

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
ACETABULAR FRACTURE			
• Mechanism: high-energy blunt trauma (e.g., MVA); fem. head into acetabulum • Fracture pattern determined by force vector & position of femoral head at impact • Multiple associated injuries: GI, GU, extremity fractures • Surgical approaches: ◦ Kocher-Langenbeck: posterior fxs (PW, PC, transverse, T type) ◦ Ilioinguinal: anterior fxs (AW, AC/HT, both columns)	**Hx:** High-energy trauma, pain, inability to WB **PE:** LE may be malrotated. Inspect skin for Morel-Lavalle lesion. Neuro exam. **XR:** AP pelvis, obturator & iliac obliques (Judet views) are essential. Roof arc angle: center of head to fx (<45° is WB) **CT:** Essential to accurately define fx (size, impaction, articular involvement, LB) & do preop planning	**Letournel & Judet:** • **Elementary fractures** ◦ Posterior wall ◦ Posterior column ◦ Anterior wall ◦ Anterior column ◦ Transverse • **Associated fractures** ◦ Post. column & post. wall ◦ Transverse & post. wall ◦ T type ◦ Ant. column and post. hemitransverse ◦ Both columns	• Reduce hip if dislocated (traction if necessary to maintain reduction) • Nonoperative: NWB for 12wk ◦ <2mm articular displacement ◦ Roof arc angle >45° ◦ Posterior wall fx <20-30% • Operative: ORIF, NWB 12wk ◦ 2mm articular displacement ◦ Posterior wall >40% ◦ Irreducible fx/dx ◦ Marginal impaction ◦ Loose bodies in hip joint • XRT for HO prophylaxis
COMPLICATIONS: Posttraumatic arthritis, nerve injury (sciatic nerve), postsurgical (heterotopic ossification [HO], sciatic nerve injury, bleeding), malunion/nonunion, infection (assoc. with Morel-Lavalle lesion), thromboembolism			

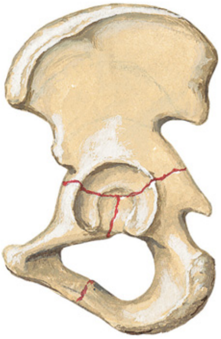
Acetabulum—Associated Fractures



Posterior column/posterior wall



Transverse/posterior wall



T-shaped fracture

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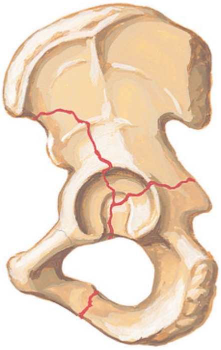
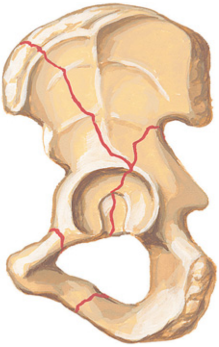
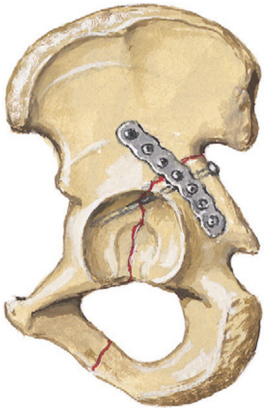


Anterior column/posterior hemi transverse

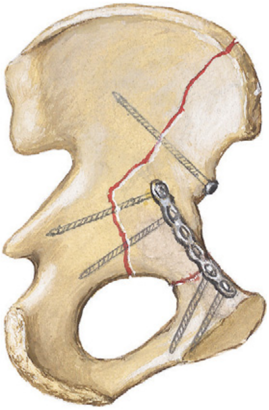


Both columns

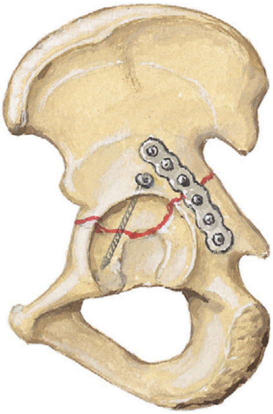
Open reduction internal fixation acetabular fracture



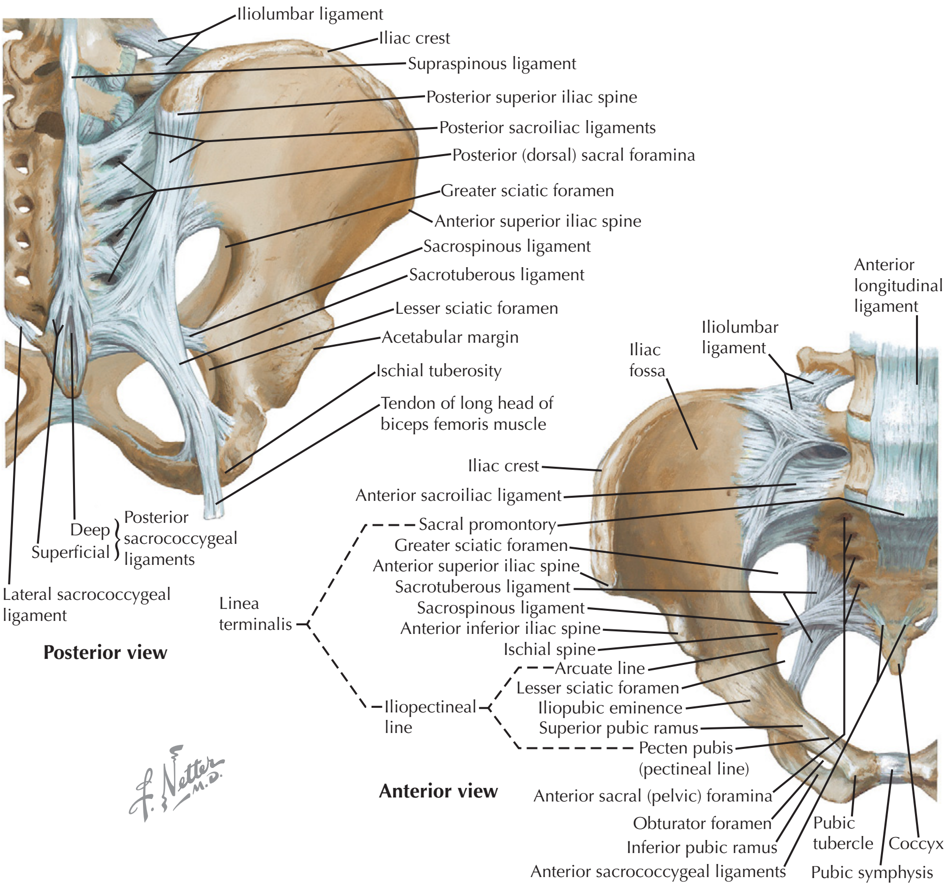
Posterior column fracture.
Repair with plate and lag screw



Anterior column fracture.
Repair with plate and long screws



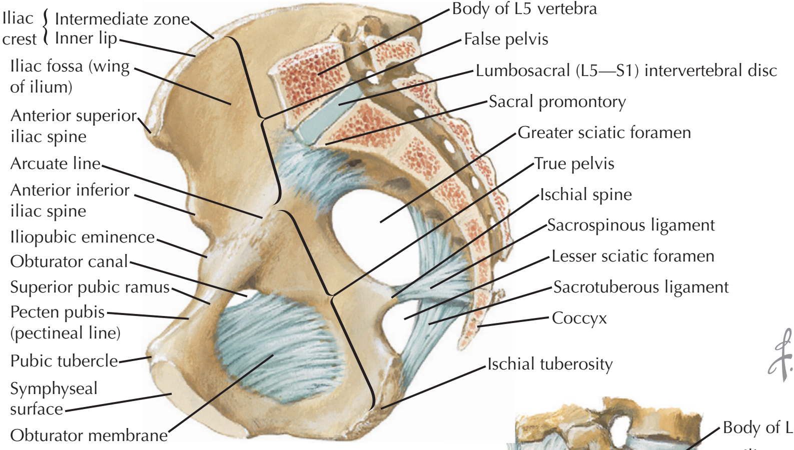
Transverse fracture.
Repair with plate and lag screw


Iliolumbar ligament
Iliac crest
Supraspinous ligament
Posterior superior iliac spine
Posterior sacroiliac ligaments
Posterior (dorsal) sacral foramina
Greater sciatic foramen
Anterior superior iliac spine
Sacrospinous ligament
Sacrotuberous ligament
Lesser sciatic foramen
Acetabular margin
Ischial tuberosity
Tendon of long head of biceps femoris muscle
Deep
Superficial
Posterior sacrococcygeal ligaments
Lateral sacrococcygeal ligament
Anterior longitudinal ligament
Iliolumbar ligament
Iliac fossa
Iliac crest
Anterior sacroiliac ligament
Sacral promontory
Greater sciatic foramen
Anterior superior iliac spine
Sacrotuberous ligament
Sacrospinous ligament
Anterior inferior iliac spine
Ischial spine
Linea terminalis
Arcuate line
Lesser sciatic foramen
Iliopectineal line
Iliopubic eminence
Superior pubic ramus
Pecten pubis (pectineal line)
Anterior sacral (pelvic) foramina
Obturator foramen
Inferior pubic ramus
Anterior sacrococcygeal ligaments
Pubic tubercle
Coccyx
Pubic symphysis

Posterior view

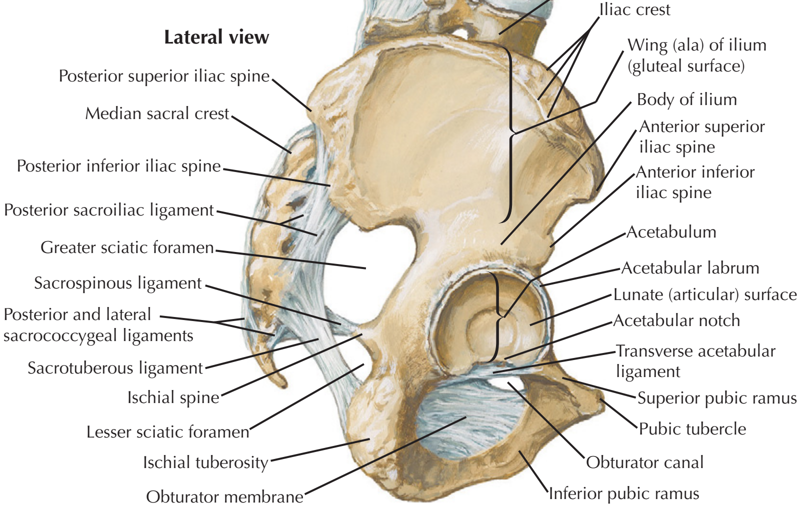
Anterior view

LIGAMENTS	ATTACHMENTS	COMMENTS
	SACROILIAC	
• This is a gliding joint. It has minimal rotational motion during gait. There should be no vertical motion in the normal joint. • Vertical stability is essential; the body weight is transmitted through this joint. • Articular surface (located inferiorly in articulation) covered with: sacrum (articular cartilage), ilium (fibrocartilage)		
Posterior sacroiliac ◦ Short sacroiliac ◦ Long sacroiliac	Posterolateral sacrum to posteromedial ilium Oblique orientation: sacrum to PSIS & PIIS Vertical orientation: sacrum to PSIS	Strongest in pelvis: key to vertical stability Resists rotational forces Resists vertical forces. Blends with sacrotuberous ligament
Anterior sacroiliac	Anterior sacrum to anterior ilium	Weaker than posterior; resists rotational forces
Interosseous	Sacrum to ilium	Adds support to anterior & posterior ligaments
	PELVIC STABILITY	
Rotational stability	Tranverse/horizontal orientation	Short posterior SI, anterior SI, sacrospinous, iliolumbar ligaments
Vertical stability	Longitudinal/vertical orientation	Long posterior SI, sacrotuberous, lumbosacral ligaments



Median (sagittal) section

Iliac crest
Intermediate zone
Inner lip
Iliac fossa (wing of ilium)
Anterior superior iliac spine
Arcuate line
Anterior inferior iliac spine
Iliopubic eminence
Obturator canal
Superior pubic ramus
Pecten pubis (pectineal line)
Pubic tubercle
Symphyseal surface
Obturator membrane
Body of L5 vertebra
False pelvis
Lumbosacral (L5—S1) intervertebral disc
Sacral promontory
Greater sciatic foramen
True pelvis
Ischial spine
Sacrospinous ligament
Lesser sciatic foramen
Sacrotuberous ligament
Coccyx
Ischial tuberosity

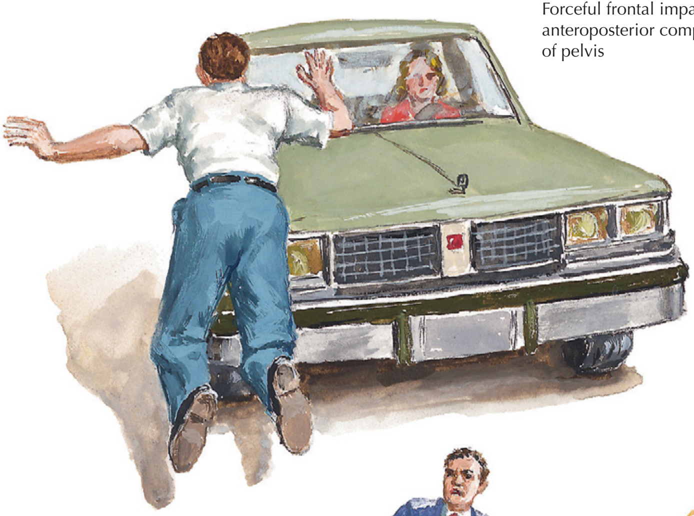


Lateral view

Posterior superior iliac spine
Median sacral crest
Posterior inferior iliac spine
Posterior sacroiliac ligament
Greater sciatic foramen
Sacrospinous ligament
Posterior and lateral sacrococcygeal ligaments
Sacrotuberous ligament
Ischial spine
Lesser sciatic foramen
Ischial tuberosity
Obturator membrane
Body of L4 vertebra
Iliac crest
Wing (ala) of ilium (gluteal surface)
Body of ilium
Anterior superior iliac spine
Anterior inferior iliac spine
Acetabulum
Acetabular labrum
Lunate (articular) surface
Acetabular notch
Transverse acetabular ligament
Superior pubic ramus
Pubic tubercle
Obturator canal
Inferior pubic ramus

LIGAMENTS	ATTACHMENTS	COMMENTS
PUBIC SYMPHYSIS		
• Anterior articulation of two hemipelves. Articulating surfaces are covered with hyaline cartilage. • Fibrocartilage disc between two pubic bones in the joint		
Superior pubic	Both pubic bones superiorly (& anteriorly)	Strongest supporting ligament
Arcuate pubic	Both pubic bones inferiorly	Muscle attachments also support inferiorly
OTHER LIGAMENTS		
Sacrospinous	Anterolateral sacrum to spinous process	Resists rotation, divides sciatic notches
Sacrotuberous	Posterolateral sacrum to ischial tuberosity	Resists vertical forces, provides vertical stability
Iliolumbar	L4 & L5 transverse process to posterior iliac crest	Avulsion fracture sign of unstable pelvic ring injury
Lumbosacral	L5 transverse process to sacral ala	Anterior support, assists in providing vertical stability

Anteroposterior compression pelvic fracture of pelvis (open book fracture)



Forceful frontal impact causes anteroposterior compression of pelvis

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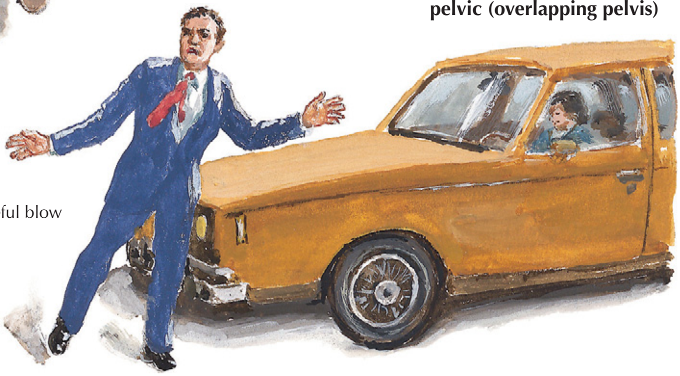
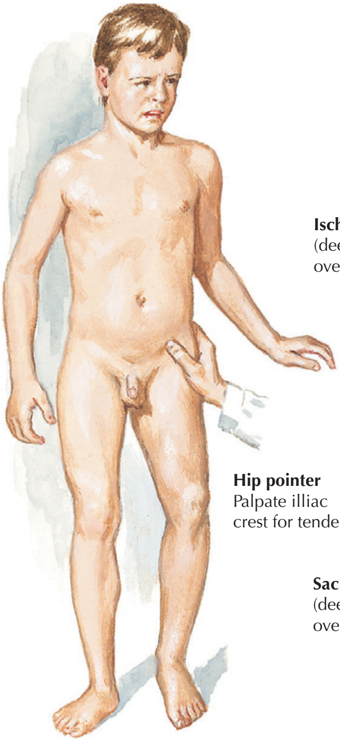
Lateral compression injury pelvic (overlapping pelvis)

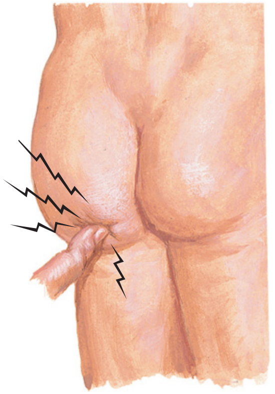


Caused by forceful blow to side of pelvis

QUESTION	ANSWER	CLINICAL APPLICATION
1. Age	Young Middle aged–elderly	Ankylosing spondylitis Sacroiliitis, decreased mobility
2. Pain		
a. Onset	Acute Chronic	Trauma: fracture, dislocation, contusion Systemic inflammatory, degenerative disorder
b. Character	Deep, non-specific Radiating	Sacroiliac etiology, infection, tumor To thigh or buttock, SI joint, L-spine
c. Occurrence	In/out of bed, on stairs Adducting legs	Sacroiliac etiology Symphysis pubis etiology
3. PMHx	Pregnancy	Laxity of ligament in SI joint causes pain
4. Trauma	Fall on buttock, twist injury High velocity: MVA, fall	Sacroiliac joint injury Fracture, pelvic ring disruption
5. Activity/work	Twisting, stand on one-leg	Sacroiliac etiology
6. Neurologic symptoms	Pain, numbness, tingling	Spine etiology, sacroiliac etiology
7. History of arthritides	Multiple joints involved	SI involvement of RA, Reiter's syndrome, ankylosing spondylitis, etc

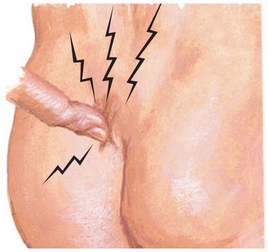


Hip pointer
Palpate illiac
crest for tenderness



With palpation

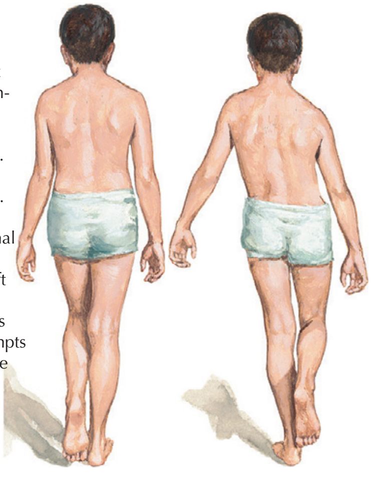
Ischial bursitis
(deep pain and tenderness
over ischial tuberosity)



With palpation

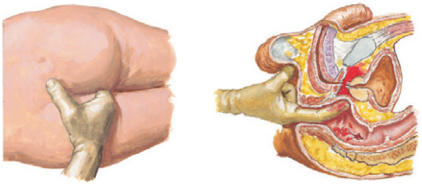
Sacroiliitis
(deep pain and tenderness
over sacroiliac joint)

EXAM/OBSERVATION	TECHNIQUE	CLINICAL APPLICATION
	INSPECTION	
Skin	Discoloration, wounds	Recent trauma
ASIS's/iliac crests	Both level (same plane)	If on different plane: leg length discrepancy, sacral torsion
Lumbar curvature	Increased lordosis Decreased lordosis	Flexion contracture Paraspinal muscle spasm
	PALPATION	
Bony structures	Standing: ASIS, pubic & iliac tubercles, PSIS Lying: iliac crest, ischial tuberosity	Unequal side to side = pelvic obliquity: leg length discrepancy "Hip pointer"/contusion, fractures Ischial bursitis ("weaver's bottom"), avulsion fx
Soft tissues	Sacroiliac joint Inguinal ligament Femoral pulse & nodes Muscle groups	Sacroiliitis Protruding mass: hernia Diminished pulse: vascular injury; palpable nodes: infection Each group should be symmetric bilaterally
	RANGE OF MOTION	
Forward flexion	Standing: bend forward	PSISs should elevate slightly (equally)
Extension	Standing: lean backward	PSISs should depress (equally)
Hip flexion	Standing: knee to chest	PSIS should drop but will elevate in hypomobile SI joint Ischial tuberosity should move laterally; will elevate in hypomobile SI joint

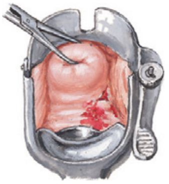


Trendelenburg test
Left: patient demonstrates negative Trendelenburg test of normal right hip. Right: positive test of involved left hip. When weight is on affected side, normal hip drops, indicating weakness of left gluteus medius muscle. Trunk shifts left as patient attempts to maintain balance

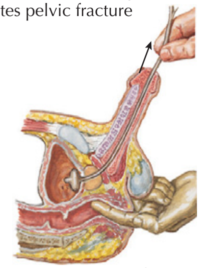
Rectal examination



Rectal examination for sphincter function and perianal sensation. Gross blood indicates pelvic fracture communicating with colon.

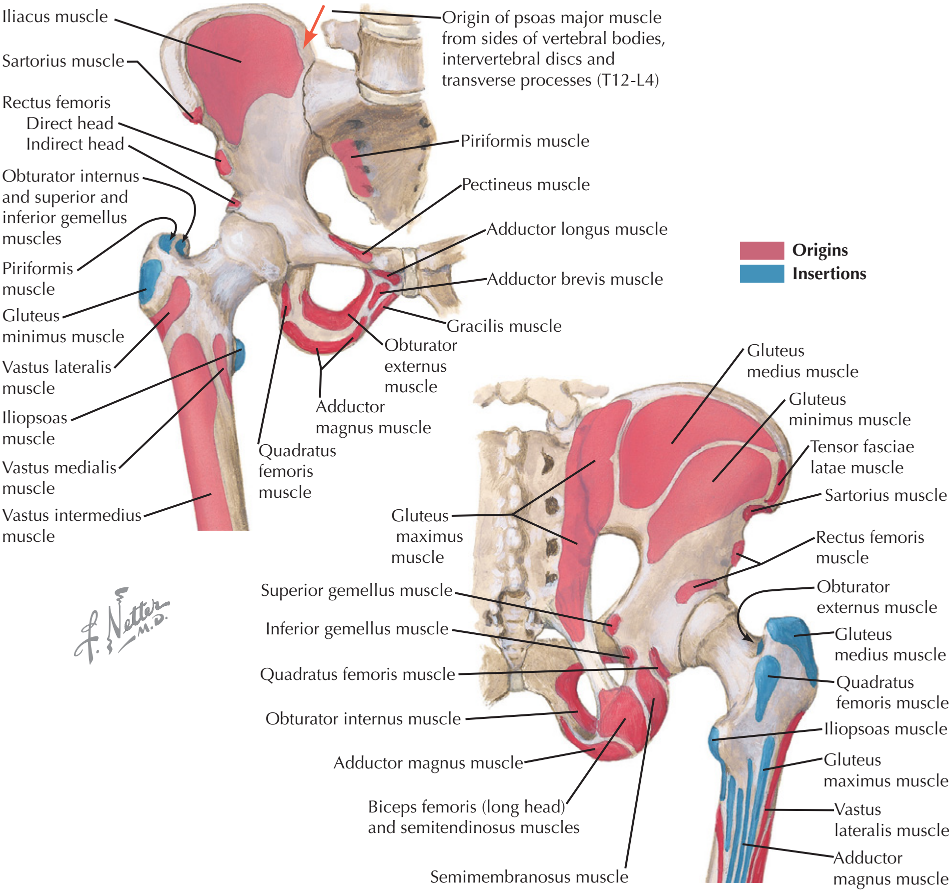


Vaginal examination



Bulbcavernosus reflex test

EXAM/OBSERVATION	TECHNIQUE	CLINICAL APPLICATION
NEUROVASCULAR		
Sensory		
Iliohypogastric nerve (L1)	Suprapubic, lat butt/thigh	Deficit indicates corresponding nerve/root lesion
Ilioinguinal nerve (L1)	Inguinal region	Deficit indicates corresponding nerve/root lesion
Genitofemoral nerve	Scrotum or mons	Deficit indicates corresponding nerve/root lesion
Lateral femoral cutaneous nerve (L2-3)	Lateral hip/thigh	Deficit indicates corresponding nerve/root lesion (e.g., meralgia paresthetica)
Pudendal nerve (S2-4)	Perineum	Deficit indicates corresponding nerve/root lesion
Motor		
Femoral (L2-4)	Hip flexion	Weakness = iliopsoas or corresponding nerve/root lesion
Inferior gluteal nerve	External rotation	Weakness = gluteus maximus or nerve/root lesion
N. to quad. femoris	External rotation	Weakness = short rotators or corresponding nerve/root lesion
Superior gluteal nerve	Abduction	Weakness = glut. med./min or nerve/root lesion
Other		
Reflex	Bulbocavernosus	Finger in rectum, squeeze or pull penis (Foley)/clitoris; anal sphincter should contract
Pulses	Femoral pulse	Diminished pulse abnormal
SPECIAL TESTS		
Pelvic rock	Push both iliac crests	Instability/motion indicates pelvic ring injury
SI stress test	Press ASIS & iliac crests	Pain in SI could be SI ligament injury
Trendelenburg sign	Standing: lift one leg (flex hip)	Flexed side: pelvis should elevate; if pelvis falls, abductor or gluteus medius (superior gluteal n.) dysfunction
Patrick (FABER)	**F**lex, **Ab**duct, **ER** hip, then abduct more	Positive if pain or LE will not continue to abduct below other leg; SI joint pathology
Meralgia	Pressure medial to ASIS	Reproduction to pain, burning, numbness = LFCN entrapment
Rectal and vaginal	Especially after trauma	Gross blood indicates trauma communicating with those organs


Iliacus muscle
Sartorius muscle
Rectus femoris
Direct head
Indirect head
Obturator internus and superior and inferior gemellus muscles
Piriformis muscle
Gluteus minimus muscle
Vastus lateralis muscle
Iliopsoas muscle
Vastus medialis muscle
Vastus intermedius muscle
Origin of psoas major muscle from sides of vertebral bodies, intervertebral discs and transverse processes (T12-L4)
Piriformis muscle
Pectineus muscle
Adductor longus muscle
Adductor brevis muscle
Gracilis muscle
Obturator externus muscle
Adductor magnus muscle
Quadratus femoris muscle
🟥 Origins
🟦 Insertions
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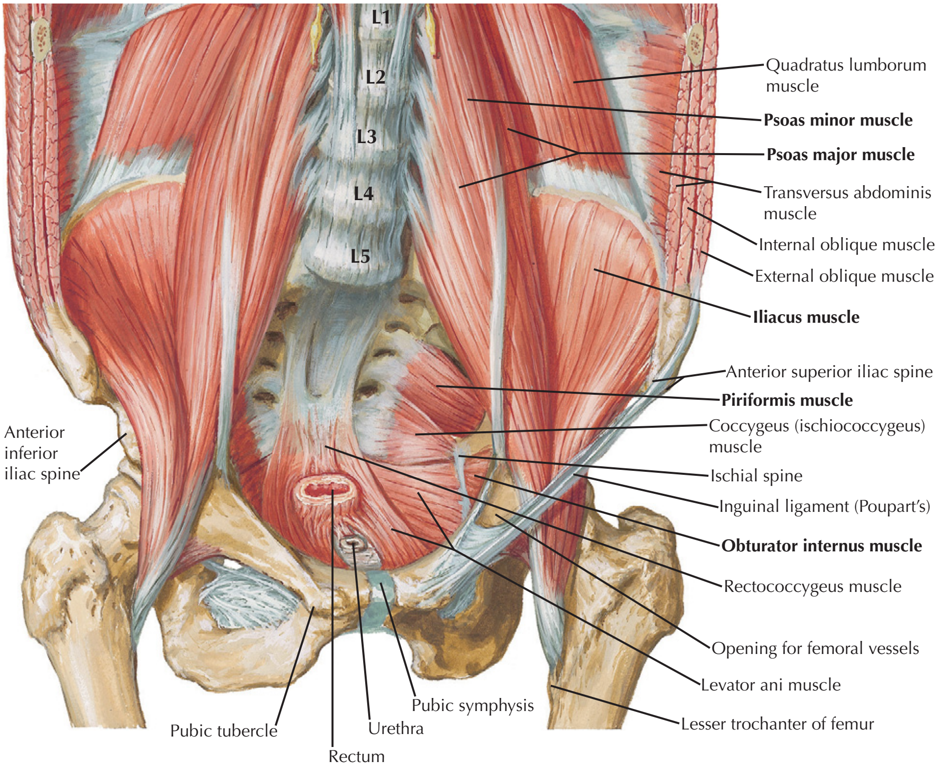
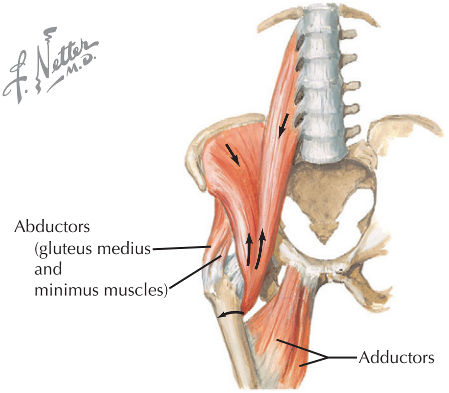
Gluteus maximus muscle
Superior gemellus muscle
Inferior gemellus muscle
Quadratus femoris muscle
Obturator internus muscle
Adductor magnus muscle
Biceps femoris (long head) and semitendinosus muscles
Semimembranosus muscle
Gluteus medius muscle
Gluteus minimus muscle
Tensor fasciae latae muscle
Sartorius muscle
Rectus femoris muscle
Obturator externus muscle
Gluteus medius muscle
Quadratus femoris muscle
Iliopsoas muscle
Gluteus maximus muscle
Vastus lateralis muscle
Adductor magnus muscle

PUBIC RAMI	GREATER TROCHANTER	ISCHIAL TUBEROSITY	LINEA ASPERA
ORIGINS			
Pectineus Adductor longus Adductor brevis Adductor magnus* Gracilis Obturator internus Obturator externus		Semimembranosus Semitendinosus Biceps femoris (LH) Adductor magnus* ***ISCHIUM*** Quadratus femoris Inferior gemellus	Vastus lateralis Vastus intermedius Vastus medialis Biceps femoris (SH)
INSERTIONS			
	Gluteus medius (posterior) Gluteus minimus (anterior) Quadratus femoris (inferior) Obturator externus (fossa) ***SHORT EXTERNAL ROTATORS*** Piriformis Superior gemellus Obturator internus Inferior gemellus		Gluteus maximus Adductor magnus Adductor brevis Adductor longus Pectineus

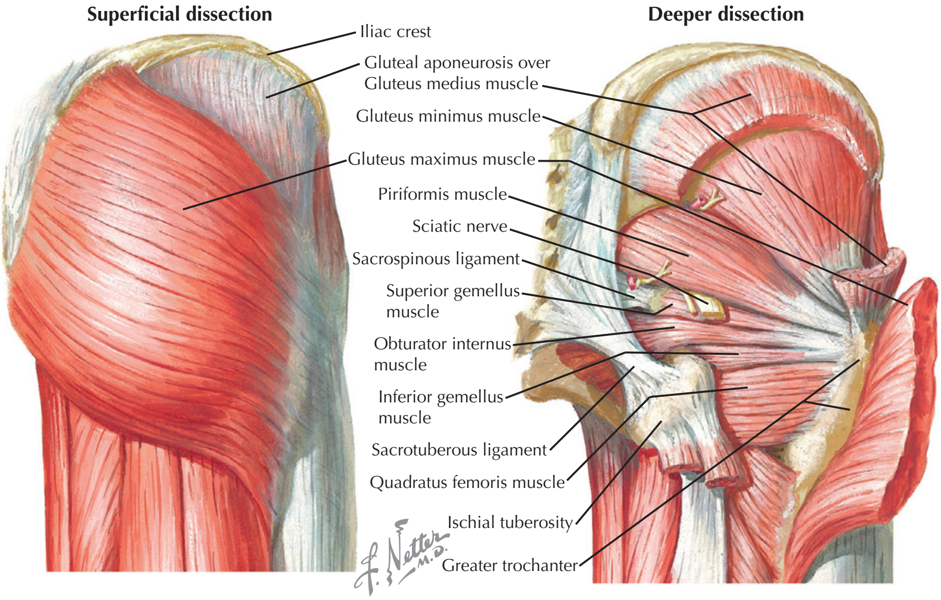
*Has two origins


L1
L2
L3
L4
L5
Quadratus lumborum muscle
Psoas minor muscle
Psoas major muscle
Transversus abdominis muscle
Internal oblique muscle
External oblique muscle
Iliacus muscle
Anterior superior iliac spine
Piriformis muscle
Coccygeus (ischiococcygeus) muscle
Ischial spine
Inguinal ligament (Poupart's)
Obturator internus muscle
Rectococcygeus muscle
Opening for femoral vessels
Levator ani muscle
Lesser trochanter of femur
Anterior inferior iliac spine
Pubic tubercle
Rectum
Urethra
Pubic symphysis


Abductors (gluteus medius and minimus muscles)
Adductors

Note: Arrows indicate direction of action of iliopsoas muscle.

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
HIP FLEXORS					
Psoas major	T12-L5 vertebrae	Lesser trochanter	Femoral	Flex hip	Covers lumbar plexus
Psoas minor	T12-L1 vertebrae	Iliopubic eminence	L1-ventral ramus	Assists in hip flexion	Weak—present in 50% of people
Iliacus	Iliac fossa/sacral ala	Lesser trochanter	Femoral	Flex hip	Covers ant. ilium
Also see muscles of the thigh/hip in Chapter 8.					


Superficial dissection
Deeper dissection
Iliac crest
Gluteal aponeurosis over Gluteus medius muscle
Gluteus minimus muscle
Gluteus maximus muscle
Piriformis muscle
Sciatic nerve
Sacrospinous ligament
Superior gemellus muscle
Obturator internus muscle
Inferior gemellus muscle
Sacrotuberous ligament
Quadratus femoris muscle
Ischial tuberosity
Greater trochanter
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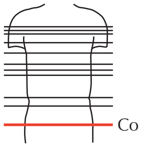
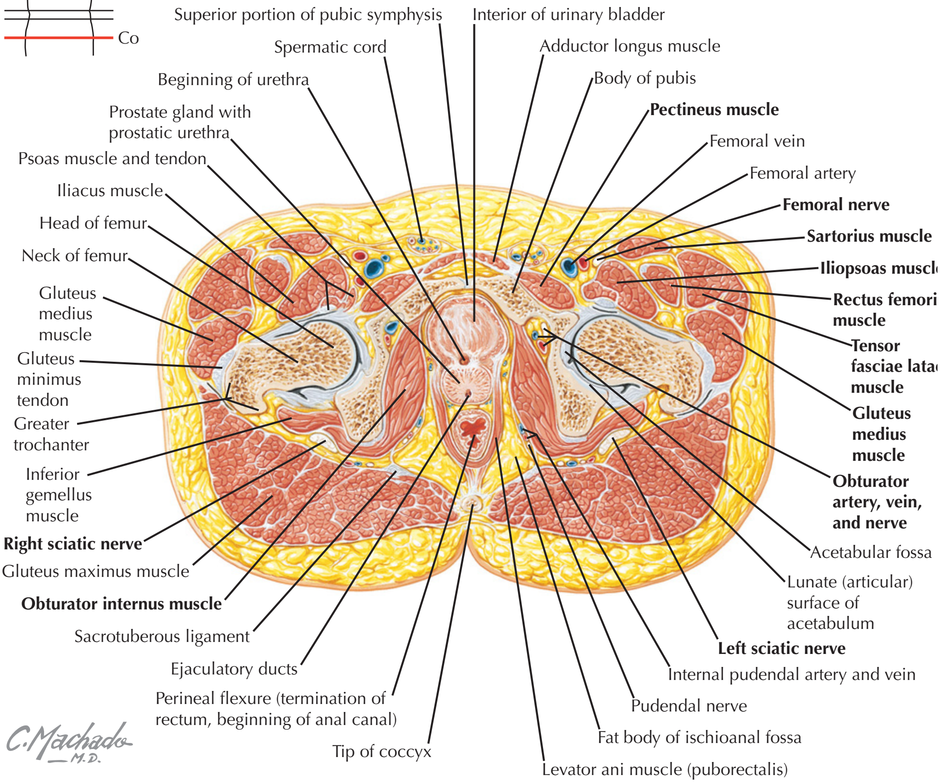
MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
HIP ABDUCTORS					
Tensor fasciae latae	Iliac crest, ASIS	Iliotibial band/ proximal tibia	Superior gluteal	Abducts, flex, IR thigh	A plane in anterior approach to hip
Gluteus medius	Ilium b/w ant. and post. gluteal lines	Greater trochanter (posterior)	Superior gluteal	Abducts, IR thigh	Trendelenburg gait if muscle is out
Gluteus minimus	Ilium b/w ant. and inf. gluteal lines	Greater trochanter (anterior)	Superior gluteal	Abducts, IR thigh	Works in conjunction with medius
HIP EXTENSORS AND EXTERNAL ROTATORS					
Gluteus maximus	Ilium, dorsal sacrum	ITB, gluteal tuberosity (femur)	Inferior gluteal	Extend, ER thigh	Must be split in posterior approach to hip
Obturator externus	Ischiopubic rami, obturator membrane	Trochanteric fossa	Obturator	ER thigh	Inserts at start point for IM nail
Short External Rotators					
Piriformis	Anterior sacrum	Superior greater trochanter	N. to piriformis	ER thigh	Used as landmark for sciatic nerve
Superior gemellus	Ischial spine	Medial greater trochanter	N. to obturator internus	ER thigh	Detached in posterior approach to hip
Obturator internus	Ischiopubic rami, obturator mem.	Medial greater trochanter	N. to obturator internus	ER, abduct thigh	Exits through lesser sciatic foramen
Inferior gemellus	Ischial tuberosity	Medial greater trochanter	N. to quadratus femoris	ER thigh	Detached in posterior approach to hip
Quadratus femoris	Ischial tuberosity	Intertrochanteric crest	N. to quadratus femoris	ER thigh	Ascending br. medial circumflex artery under muscle



Transverse Section: Pubic Crest, Femoral Heads, Coccyx


Superior portion of pubic symphysis
Interior of urinary bladder
Spermatic cord
Adductor longus muscle
Beginning of urethra
Body of pubis
Prostate gland with prostatic urethra
Pectineus muscle
Psoas muscle and tendon
Femoral vein
Femoral artery
Iliacus muscle
Femoral nerve
Head of femur
Sartorius muscle
Neck of femur
Iliopsoas muscl
Gluteus medius muscle
Rectus femori muscle
Gluteus minimus tendon
Tensor fasciae lata muscle
Greater trochanter
Gluteus medius muscle
Inferior gemellus muscle
Obturator artery, vein, and nerve
Right sciatic nerve
Acetabular fossa
Gluteus maximus muscle
Lunate (articular) surface of acetabulum
Obturator internus muscle
Left sciatic nerve
Sacrotuberous ligament
Internal pudendal artery and vein
Ejaculatory ducts
Pudendal nerve
Perineal flexure (termination of rectum, beginning of anal canal)
Fat body of ischioanal fossa
Tip of coccyx
Levator ani muscle (puborectalis)
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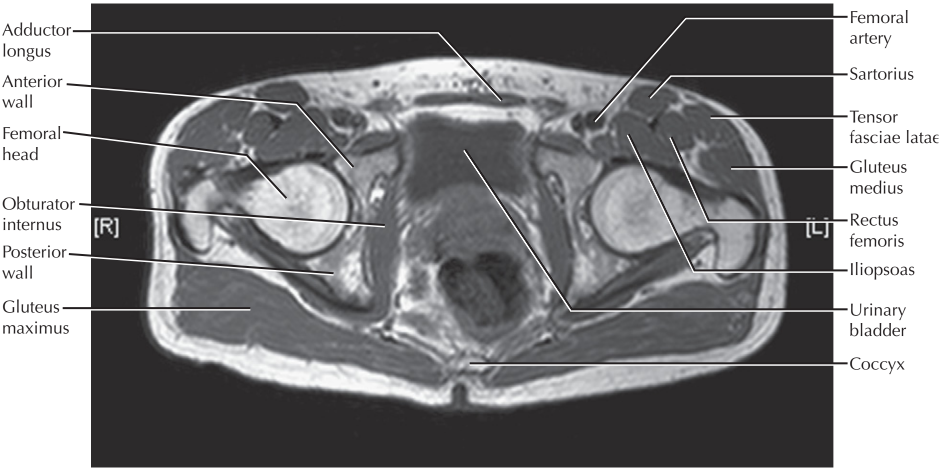
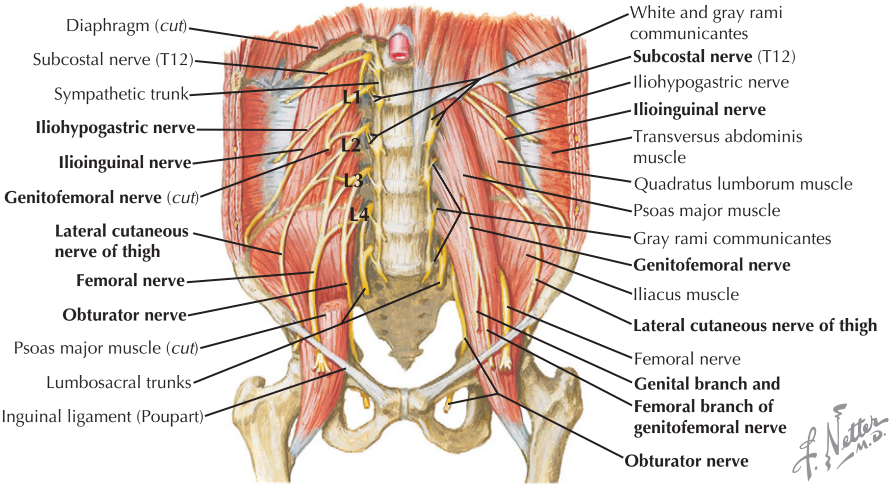
MRI pelvis


Adductor longus
Femoral artery
Anterior wall
Sartorius
Femoral head
Tensor fasciae latae
Gluteus medius
Obturator internus
[R]
[L]
Rectus femoris
Posterior wall
Iliopsoas
Gluteus maximus
Urinary bladder
Coccyx


Diaphragm (*cut*)
Subcostal nerve (T12)
Sympathetic trunk
Iliohypogastric nerve
Ilioinguinal nerve
Genitofemoral nerve (*cut*)
Lateral cutaneous nerve of thigh
Femoral nerve
Obturator nerve
Psoas major muscle (*cut*)
Lumbosacral trunks
Inguinal ligament (Poupart)
L1
L2
L3
L4
White and gray rami communicantes
Subcostal nerve (T12)
Iliohypogastric nerve
Ilioinguinal nerve
Transversus abdominis muscle
Quadratus lumborum muscle
Psoas major muscle
Gray rami communicantes
Genitofemoral nerve
Iliacus muscle
Lateral cutaneous nerve of thigh
Femoral nerve
Genital branch and Femoral branch of genitofemoral nerve
Obturator nerve
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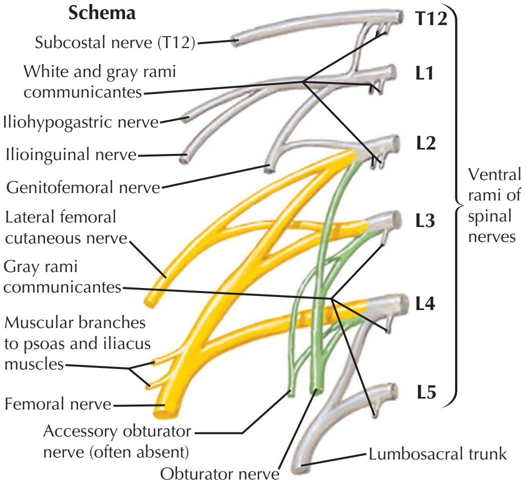
Schema


Subcostal nerve (T12)
White and gray rami communicantes
Iliohypogastric nerve
Ilioinguinal nerve
Genitofemoral nerve
Lateral femoral cutaneous nerve
Gray rami communicantes
Muscular branches to psoas and iliacus muscles
Femoral nerve
Accessory obturator nerve (often absent)
Obturator nerve
Lumbosacral trunk
T12
L1
L2
L3
L4
L5
Ventral rami of spinal nerves

LUMBAR PLEXUS

Lumbar plexus comprises the ventral rami of L1-L4. Two divisions: anterior (innervates flexors), posterior (extensors). Plexus formed within the psoas muscle.

Anterior Division

Subcostal (T12): Inferior to 12th rib

Sensory: Subxyphoid region
Motor: None

Iliohypogastric (L1): Under psoas, pierces abdominal muscles

Sensory: Above pubis
Posterolateral buttocks
Motor: Transversus abdominis
Internal oblique

Ilioinguinal (L1): Under psoas, pierces abdominal muscles

Sensory: Inguinal region, anterosuperior thigh
Motor: None

Genitofemoral(L1-2): Pierces psoas lies on anterior surface of psoas muscle

Sensory Scrotum or labia majora
Motor: Cremaster

Obturator (L2-4): Exits via obturator canal, splits into ant. & post. division (can be injured by retractors placed behind the transverse acetabular ligament [TAL])

Sensory: Inferomedial thigh via **cut. br. of obturator n.**
Motor: External oblique
Obturator externus (posterior division)

Accessory Obturator (L2-4): Inconsistent

Sensory: None
Motor: Psoas

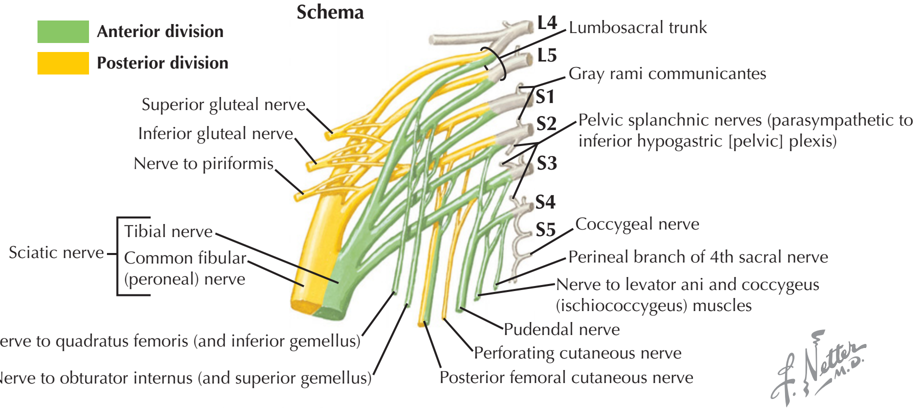
Posterior Division

Lateral Femoral Cutaneous (FFCN) (L2-3): runs on iliacus, crosses inferior to ASIS (can be compressed there: meralgia paresthetica)

Sensory: None (in pelvis)
Motor: None

Femoral (L2-4): Lies between psoas major and iliacus

Sensory: None (in pelvis)
Motor: Psoas
Iliacus
Pectineus



Schema

🟩 Anterior division
🟨 Posterior division
L4
L5
S1
S2
S3
S4
S5
Lumbosacral trunk
Gray rami communicantes
Pelvic splanchnic nerves (parasympathetic to inferior hypogastric [pelvic] plexis)
Coccygeal nerve
Perineal branch of 4th sacral nerve
Nerve to levator ani and coccygeus (ischiococcygeus) muscles
Pudendal nerve
Perforating cutaneous nerve
Posterior femoral cutaneous nerve
Superior gluteal nerve
Inferior gluteal nerve
Nerve to piriformis
Sciatic nerve
Tibial nerve
Common fibular (peroneal) nerve
Nerve to quadratus femoris (and inferior gemellus)
Nerve to obturator internus (and superior gemellus)
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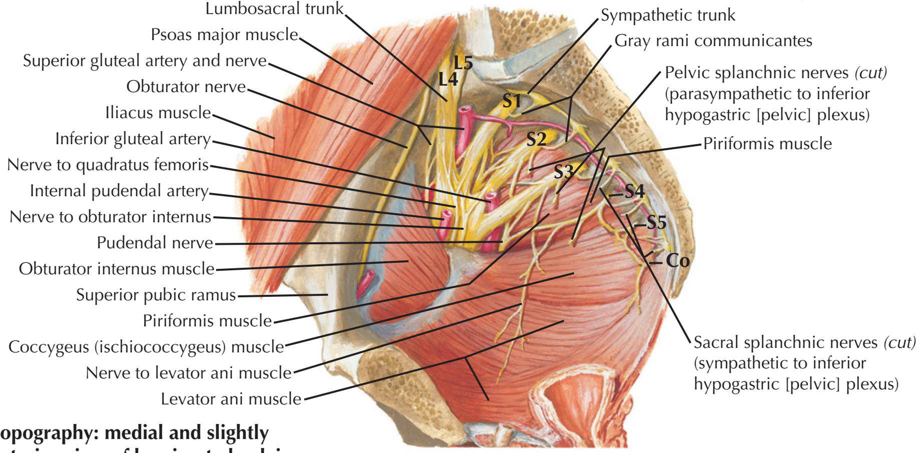
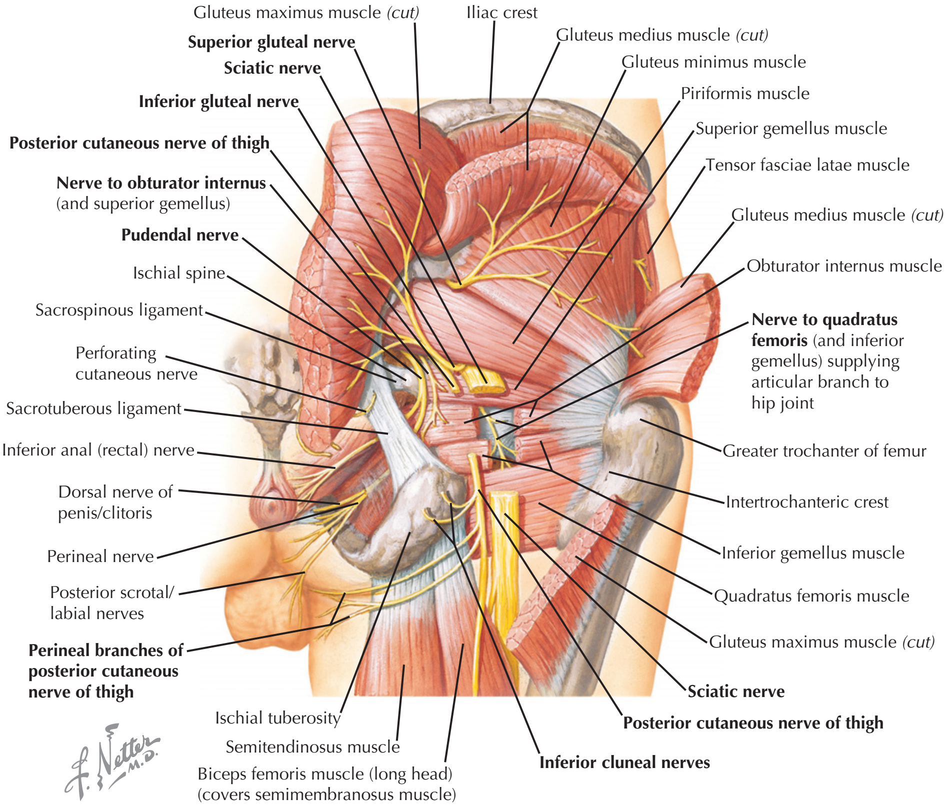


Lumbosacral trunk
Psoas major muscle
Superior gluteal artery and nerve
Obturator nerve
Iliacus muscle
Inferior gluteal artery
Nerve to quadratus femoris
Internal pudendal artery
Nerve to obturator internus
Pudendal nerve
Obturator internus muscle
Superior pubic ramus
Piriformis muscle
Coccygeus (ischiococcygeus) muscle
Nerve to levator ani muscle
Levator ani muscle
L4
L5
S1
S2
S3
S4
S5
Co
Sympathetic trunk
Gray rami communicantes
Pelvic splanchnic nerves (cut) (parasympathetic to inferior hypogastric [pelvic] plexus)
Piriformis muscle
Sacral splanchnic nerves (cut) (sympathetic to inferior hypogastric [pelvic] plexus)

Topography: medial and slightly anterior view of hemisected pelvis

LUMBOSACRAL PLEXUS	
Lumbosacral plexus comprises the ventral rami of L4-S3(4). Two divisions: Anterior (innervates flexors), posterior (extensors). Plexus lies on anterior piriformis muscle.	
Anterior Division	
Nerve to quadratus femoris (L4-S1): Exits greater sciatic foramen *Sensory:* None *Motor:* Quadratus femoris Inferior gemelli **Nerve to obturator internus (L5-S2):** Exits greater sciatic foramen *Sensory:* None *Motor:* Obturator internus Superior gemelli	**Pudendal (S2-4):** Exits greater then re-enters pelvis through lesser sciatic foramen *Sensory:* Perineum: via **perineal nerve** (scrotal/labial br.) via **inferior rectal nerve** via **dorsal nerve** to penis/clitoris *Motor:* Bulbospongiosus: **perineal nerve** Ischiocavernosus: **perineal nerve** Urethral sphincter: **perineal nerve** Urogenital diaphragm: **perineal nerve** Sphincter ani externus: **inferior rectal nerve** **Nerve to coccygeus (S3-4):** directly innervates muscle *Sensory:* None *Motor:* Coccygeus Levator ani


Gluteus maximus muscle *(cut)*
Iliac crest
Superior gluteal nerve
Sciatic nerve
Inferior gluteal nerve
Posterior cutaneous nerve of thigh
Nerve to obturator internus (and superior gemellus)
Pudendal nerve
Ischial spine
Sacrospinous ligament
Perforating cutaneous nerve
Sacrotuberous ligament
Inferior anal (rectal) nerve
Dorsal nerve of penis/clitoris
Perineal nerve
Posterior scrotal/ labial nerves
Perineal branches of posterior cutaneous nerve of thigh
Ischial tuberosity
Semitendinosus muscle
Biceps femoris muscle (long head) (covers semimembranosus muscle)
Gluteus medius muscle *(cut)*
Gluteus minimus muscle
Piriformis muscle
Superior gemellus muscle
Tensor fasciae latae muscle
Gluteus medius muscle *(cut)*
Obturator internus muscle
Nerve to quadratus femoris (and inferior gemellus) supplying articular branch to hip joint
Greater trochanter of femur
Intertrochanteric crest
Inferior gemellus muscle
Quadratus femoris muscle
Gluteus maximus muscle *(cut)*
Sciatic nerve
Posterior cutaneous nerve of thigh
Inferior cluneal nerves
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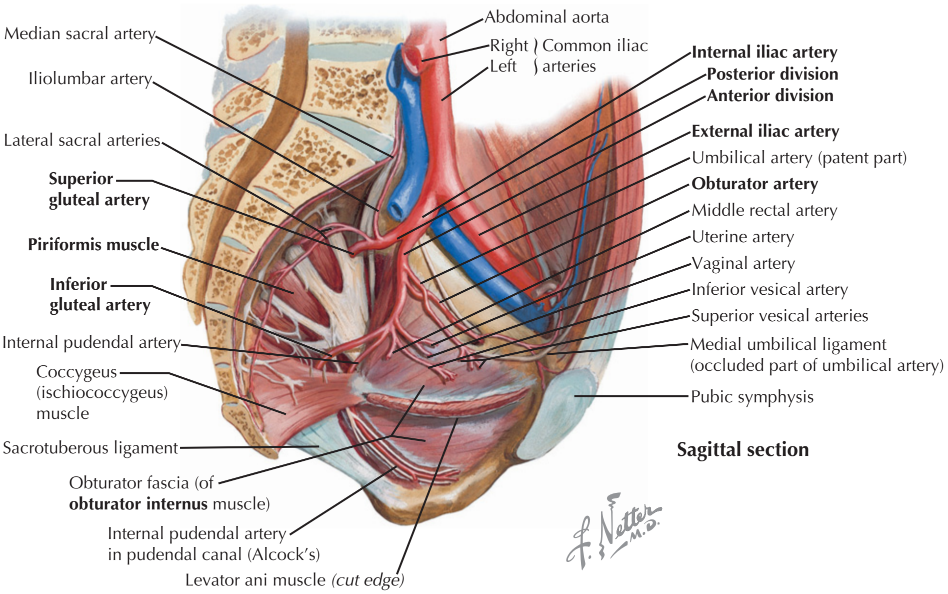
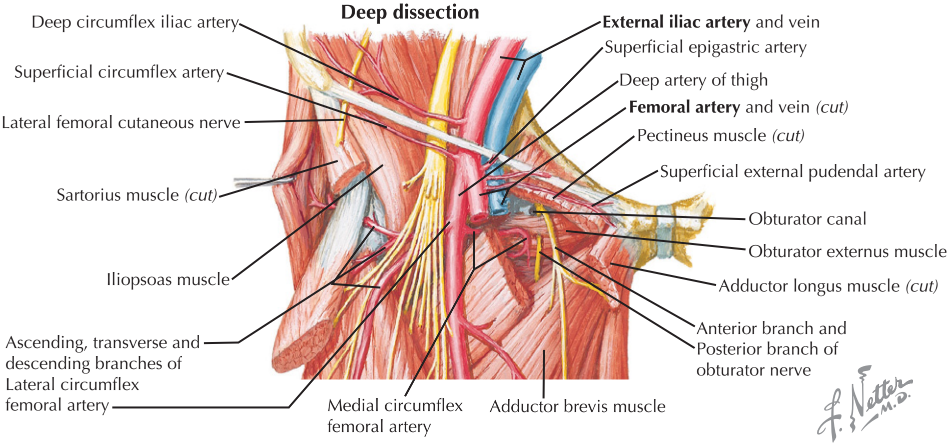
LUMBOSACRAL PLEXUS	
Posterior Division	**Both Divisions**
Superior Gluteal (L4-S1): Exits greater sciatic foramen above the piriformis *Sensory:* None *Motor:* Gluteus medius Gluteus minimus Tensor fasciae latae **Inferior Gluteal (L5-S2):** Exits greater sciatic foramen *Sensory:* None *Motor:* Gluteus maximus **Nerve to Piriformis (S2):** Directly innervates muscle *Sensory:* None *Motor:* Piriformis	**Posterior Femoral Cutaneous (S1-S3):** Exits via greater sciatic foramen, under piriformis, medial to sciatic nerve *Sensory:* Inferior buttocks: via **inferior cluneal nerves** Posterior perineum: **perineal branches** Posterior thigh (see Chapter 8) *Motor:* None **Sciatic (L4-S3):** Largest nerve in body. Two components: tibial (ant. division) and peroneal (post. division). Exits greater sciatic foramen under piriformis. Anatomic variants include exiting through or above piriformis. Reflecting short ERs will protect sciatic in posterior approach to hip. *Sensory:* None (in pelvis; see Chapters 8-10) *Motor:* None (in pelvis; see Chapters 8-10)
Other Nerves (Nonplexus)	
Superior Cluneal (L1-3): Branches of dorsal rami. *Sensory:* Superior ⅔ of buttocks	**Medial Cluneal (S1-3):** Branches of dorsal rami *Sensory:* Sacral and medial buttocks
• Piriformis muscle is the landmark in gluteal region. Most nerves exit inferior to it. **POP'S IQ** is a mnemonic: **P**udendal, N. to **O**bturator internus, **P**osterior cutaneous, **S**ciatic, **I**nferior gluteal, N. to **Q**uadratus femoris.	


Median sacral artery
Iliolumbar artery
Lateral sacral arteries
Superior gluteal artery
Piriformis muscle
Inferior gluteal artery
Internal pudendal artery
Coccygeus (ischiococcygeus) muscle
Sacrotuberous ligament
Obturator fascia (of **obturator internus** muscle)
Internal pudendal artery in pudendal canal (Alcock's)
Levator ani muscle *(cut edge)*
Abdominal aorta
Right } Common iliac
Left } arteries
Internal iliac artery
Posterior division
Anterior division
External iliac artery
Umbilical artery (patent part)
Obturator artery
Middle rectal artery
Uterine artery
Vaginal artery
Inferior vesical artery
Superior vesical arteries
Medial umbilical ligament (occluded part of umbilical artery)
Pubic symphysis

Sagittal section

ARTERY	COURSE	COMMENT/SUPPLY
	AORTA	
Common iliacs	Branch at L4, run along anterior spine	Blood supply to pelvis & lower extremities
Median sacral	Descends along anterior spine & sacrum	Anastomoses with lateral sacral arteries
	COMMON ILIAC ARTERY	
Internal iliac	Under ureter toward sacrum, then divides	Supplies most of pelvis & pelvic organs Divides into anterior & posterior divisions
External iliac	On ant. surface of psoas to inguinal ligament	Does not supply much of the pelvis
	INTERNAL ILIAC	
	Anterior Division	
Obturator	Through obturator foramen w/obturator nerve	Fovea artery (ligamentum teres) branches
Inferior gluteal	Exits greater sciatic foramen under piriformis	Supplies gluteus maximus muscle
Multiple visceral branches	Umbilical Uterine/vaginal (females) Inferior vesical (males) Middle rectal Internal pudendal	Supplies bladder (via sup. vesical arteries) Supplies uterus & vagina (via vaginal br.) Supplies bladder, prostate, ductus deferens Anastomoses w/sup. & inf. rectal arteries Runs with pudendal nerve Inferior rectal art. branches from this artery
	Posterior Division	
Superior gluteal	Exits greater sciatic foramen above piriformis	In sciatic notch, can be injured in posterior column fractures or pelvic ring injuries
Iliolumbar	Runs superiorly toward iliac fossa	Supplies ilium, iliacus, & psoas muscles
Lateral sacral	Run along sacrum, anterior to the sacral roots	Supplies sacrum/sacral muscles/nerves Anastomoses w/median sacral art. (aorta)


Deep dissection
Deep circumflex iliac artery
Superficial circumflex artery
Lateral femoral cutaneous nerve
Sartorius muscle (cut)
Iliopsoas muscle
Ascending, transverse and descending branches of Lateral circumflex femoral artery
Medial circumflex femoral artery
Adductor brevis muscle
External iliac artery and vein
Superficial epigastric artery
Deep artery of thigh
Femoral artery and vein (cut)
Pectineus muscle (cut)
Superficial external pudendal artery
Obturator canal
Obturator externus muscle
Adductor longus muscle (cut)
Anterior branch and Posterior branch of obturator nerve
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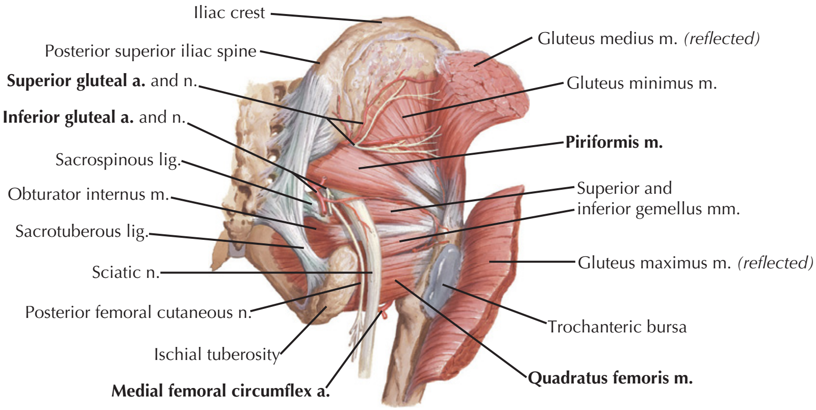
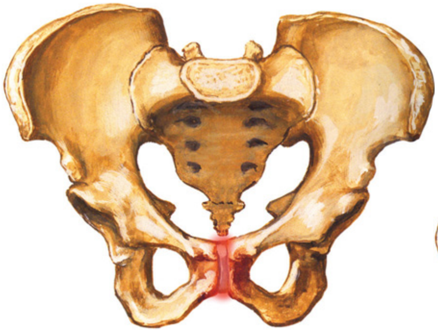
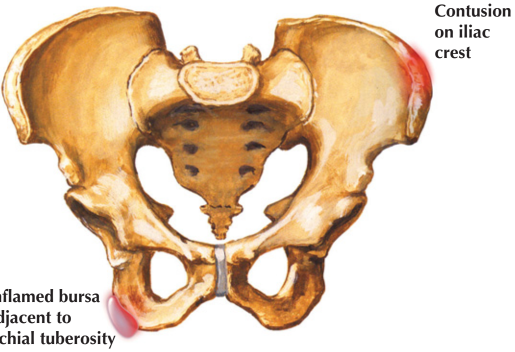

Iliac crest
Posterior superior iliac spine
Superior gluteal a. and n.
Inferior gluteal a. and n.
Sacrospinous lig.
Obturator internus m.
Sacrotuberous lig.
Sciatic n.
Posterior femoral cutaneous n.
Ischial tuberosity
Medial femoral circumflex a.
Gluteus medius m. (reflected)
Gluteus minimus m.
Piriformis m.
Superior and inferior gemellus mm.
Gluteus maximus m. (reflected)
Trochanteric bursa
Quadratus femoris m.

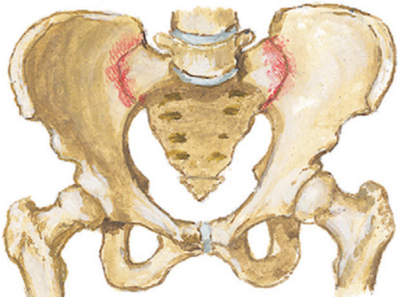
ARTERY	COURSE	COMMENT/SUPPLY
EXTERNAL ILIAC ARTERY		
Deep circumflex iliac	Runs laterally under internal oblique to iliac crest	Supplies anterolateral abdominal wall muscles
Inferior epigastric	Runs superiorly in transversalis fascia	Supplies anterior abdominal wall muscles
Femoral artery	Continuation of EIA under inguinal ligament	Terminal branch of external iliac artery
FEMORAL ARTERY		
Superficial circumflex iliac	In subcutaneous tissues toward ASIS	Supplies superficial abdominal tissues
Superficial epigastric	In subcutaneous tissues toward umbilicus	Supplies superficial abdominal tissues
Superficial & deep external pudendal	Medially over the adductors & spermatic cord to inguinal and genital regions	Supplies subcutaneous tissues in the pubic region and the scrotum/labia majus
Profunda femoris (deep artery of thigh)	Between adductor longus & pectineus/ adductor brevis	Gives off circumflex (2) & perforating branches
Medial circumflex femoral	B/w pectineus & psoas, then posterior to femoral neck under quadratus femoris	Runs under quadratus femoris; can be injured in posterior approach to hip
Lateral circumflex femoral	Runs laterally deep to sartorius & rectus	At risk in anterolateral approach to hip



Osteitis pubis

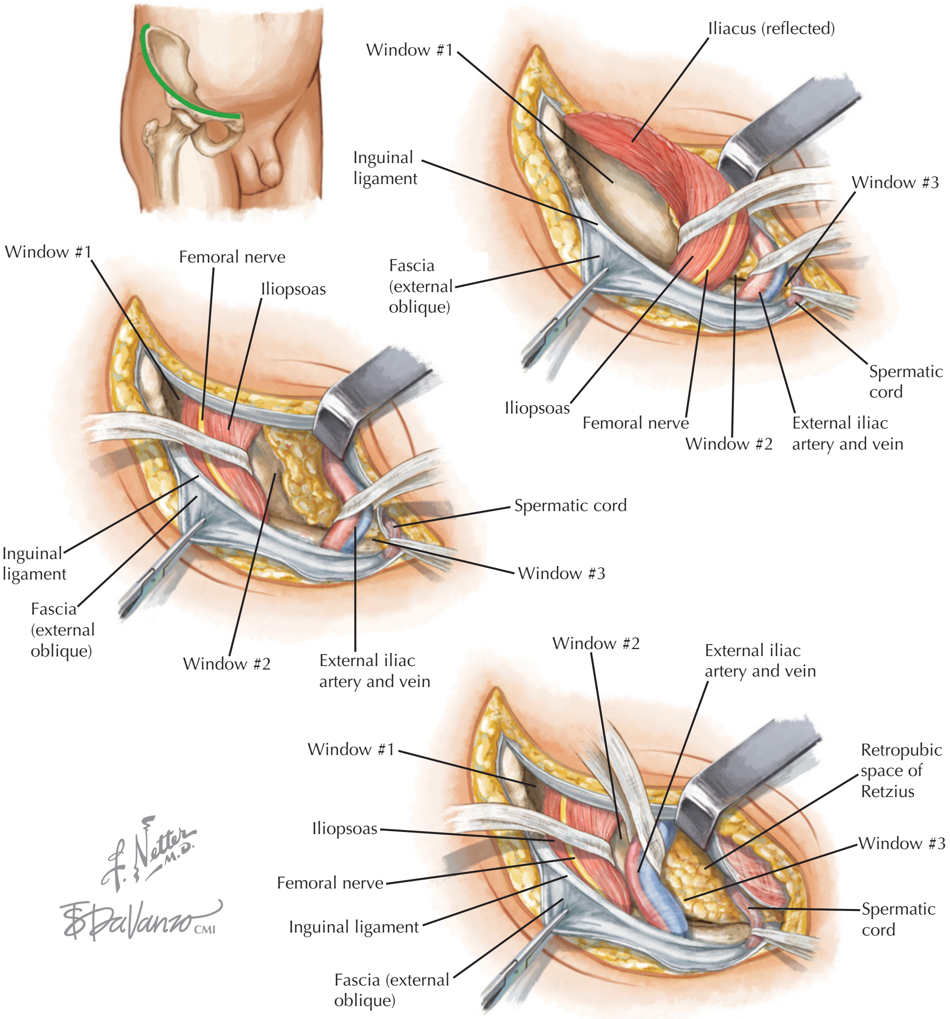


Ischial tuberosity and hip pointer



Sacroiliitis

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
OSTEITIS PUBIS			
• Inflammation or degeneration of pubic symphysis • Etiology: repetitive microtrauma (sports) or fracture	**Hx:** Anterior pelvic pain, sports or trauma **PE:** Symphysis pubis is tender to palpation	**XR:** AP pelvis (+/– inlet & outlet views) **CT/MR:** Not usually necessary for diagnosis	1. Activity modification 2. Rest, NSAIDs 3. Fusion if symptoms are refractory to conservative care
SACROILIITIS			
• Inflammation or degeneration of sacroiliac joint • Infection can also occur here • Assoc. w/Reiter's syndrome	**Hx:** Low back pain **PE:** SIJ tender to palpation, + FABER test; injection can help diagnosis	**XR/CT:** SI joints, +/– DJD **Bone Scan:** r/o infection **LABS:** CBC, ESR, CRP if infection is suspected	1. Rest, NSAIDs 2. Injection can be diagnostic & therapeutic (corticosteroid) 3. Fusion: rarely indicated
ISCHIAL BURSITIS			
• Inflammation of bursa of ischial tuberosity • Often from prolonged sitting • Aka "weaver's bottom" • Mimics hamstring injury	**Hx:** Buttocks pain, sitting **PE:** Ischial tuberosity tender to palpation; active hamstrings NOT painful	**XR:** Pelvis, r/o tuberosity avulsion **MR:** Can evaluate/ r/o hamstring insertion injury	1. Rest 2. NSAIDs 3. Activity modification: decrease sitting or increase cushion
ILIAC CREST CONTUSION (HIP POINTER)			
• Direct trauma to iliac crest • Common in contact sports (e.g., football, hockey, etc)	**Hx:** Trauma, "hip" pain **PE:** Iliac crest tender to palpation	**XR:** Pelvis, r/o fracture **MR/CT:** Usually not necessary for diagnosis	1. Rest, NSAIDs 2. Padding to iliac crest 3. Corticosteroid injection


Window #1
Iliacus (reflected)
Inguinal ligament
Window #3
Fascia (external oblique)
Spermatic cord
Iliopsoas
Femoral nerve
Window #2
External iliac artery and vein
Window #1
Femoral nerve
Iliopsoas
Spermatic cord
Window #3
Inguinal ligament
Fascia (external oblique)
Window #2
External iliac artery and vein
Window #2
External iliac artery and vein
Window #1
Retropubic space of Retzius
Iliopsoas
Window #3
Femoral nerve
Spermatic cord
Inguinal ligament
Fascia (external oblique)
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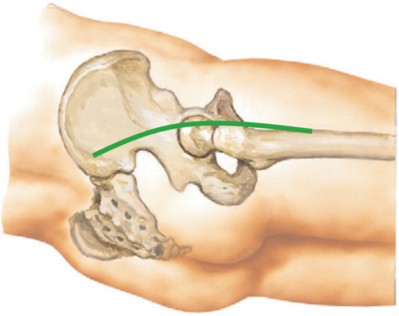
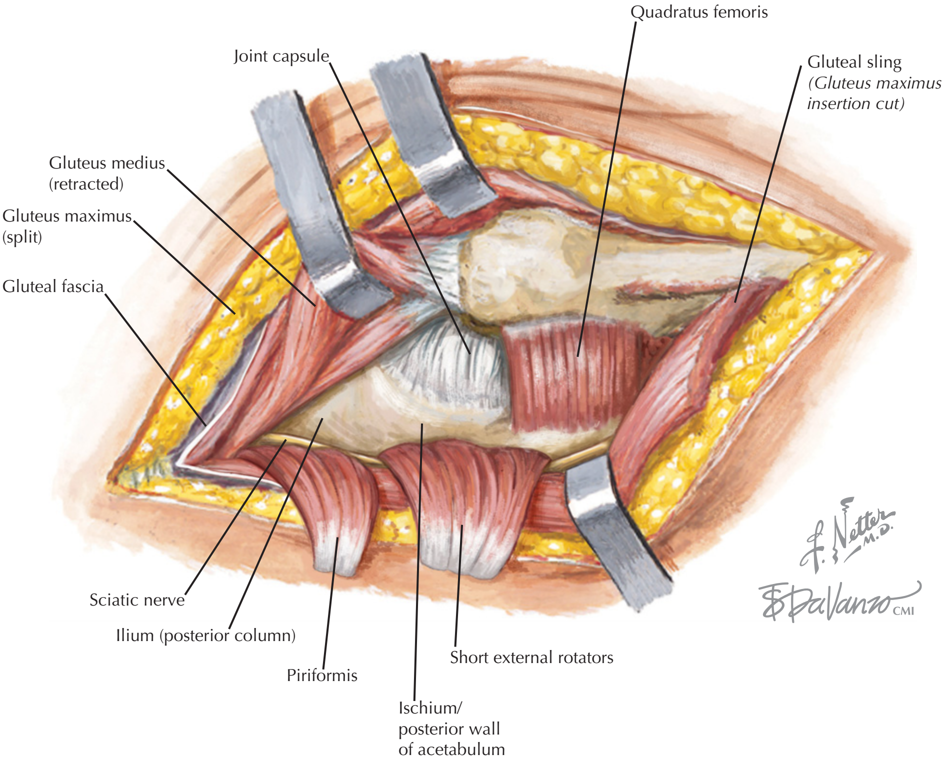
USES	INTERNERVOUS PLANE	DANGERS	COMMENT
ILIOINGUINAL APPROACH			
• Open reduction, internal fixation of acetabular fractures involving anterior column of acetabulum	3 windows—interval (access): **1.** Lateral to iliopsoas & femoral nerve (anterior, SIJ, iliac fossa, pelvic brim) **2.** Between iliopsoas/femoral nerve & external iliac artery (pelvic brim, lateral superior pubic ramus) **3.** Medial to external iliac artery & spermatic cord (quadrilateral plate & retropubic space [of Retzius])	• Ext. iliac (EI) vessels • Corona mortis (vessel from obt. art. to EI art.) • Femoral nerve • Lateral femoral cutaneous nerve • Inferior epigastric artery • Spermatic cord • Bladder (use a Foley)	• Good knowledge of abdominal & pelvic anatomy essential to perform this approach • Must detach pelvic insertion of abdominal muscles & iliacus muscle for exposure • Use rubber drains around iliopsoas/femoral n. & external iliac vessels to access windows




Quadratus femoris
Joint capsule
Gluteal sling
(Gluteus maximus insertion cut)
Gluteus medius (retracted)
Gluteus maximus (split)
Gluteal fascia
Sciatic nerve
Ilium (posterior column)
Piriformis
Short external rotators
Ischium/ posterior wall of acetabulum

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
KOCHER-LANGENBECK APPROACH			
• Open reduction, internal fixation of acetabular fractures involving posterior column of acetabulum	No internervous plane • Gluteus maximus (inf. gluteal n.) fascia is split in line with its fibers; inferior gluteal nerve is limit to the split. • Tensor fasciae latae also split in line with its fibers	• Sciatic nerve • Inferior gluteal artery • Superior gluteal vessels & nerve (esp. w/excessive retraction)	• Heterotopic ossification is common, prophylaxis (e.g., XRT) is often needed. • Do not take down quadratus femoris due to vascular risk

CHAPTER 8

Thigh/Hip

Topographic Anatomy 250
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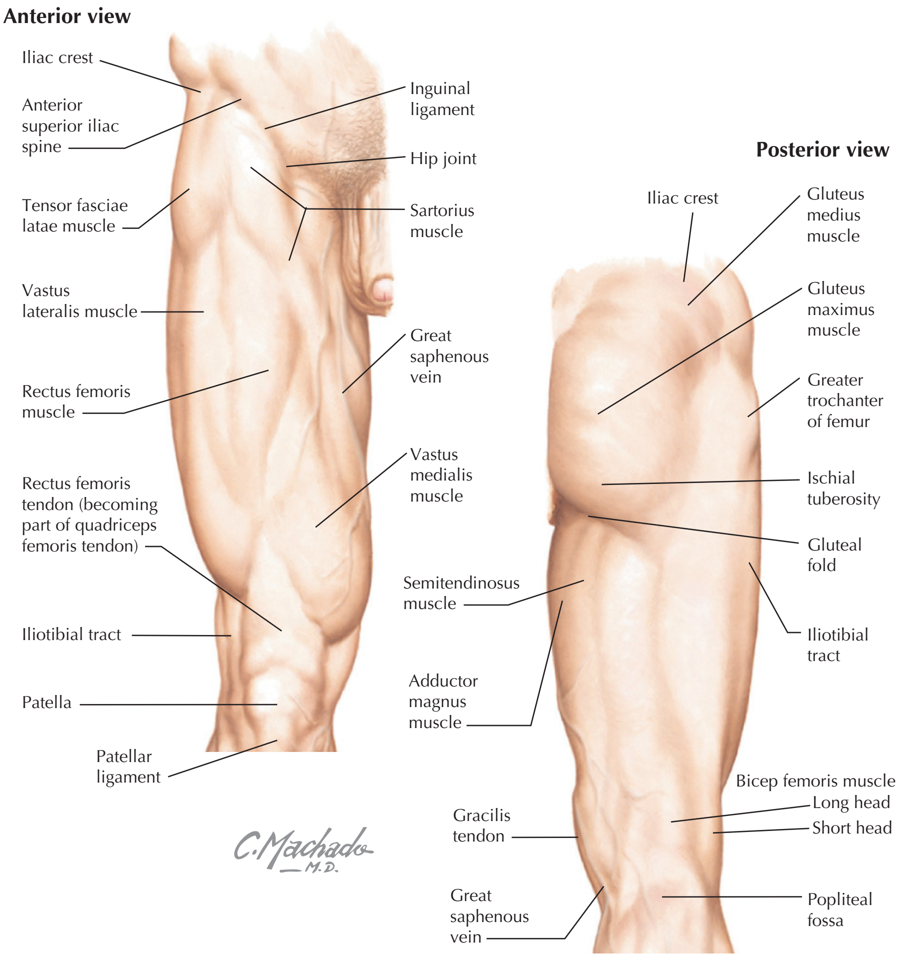
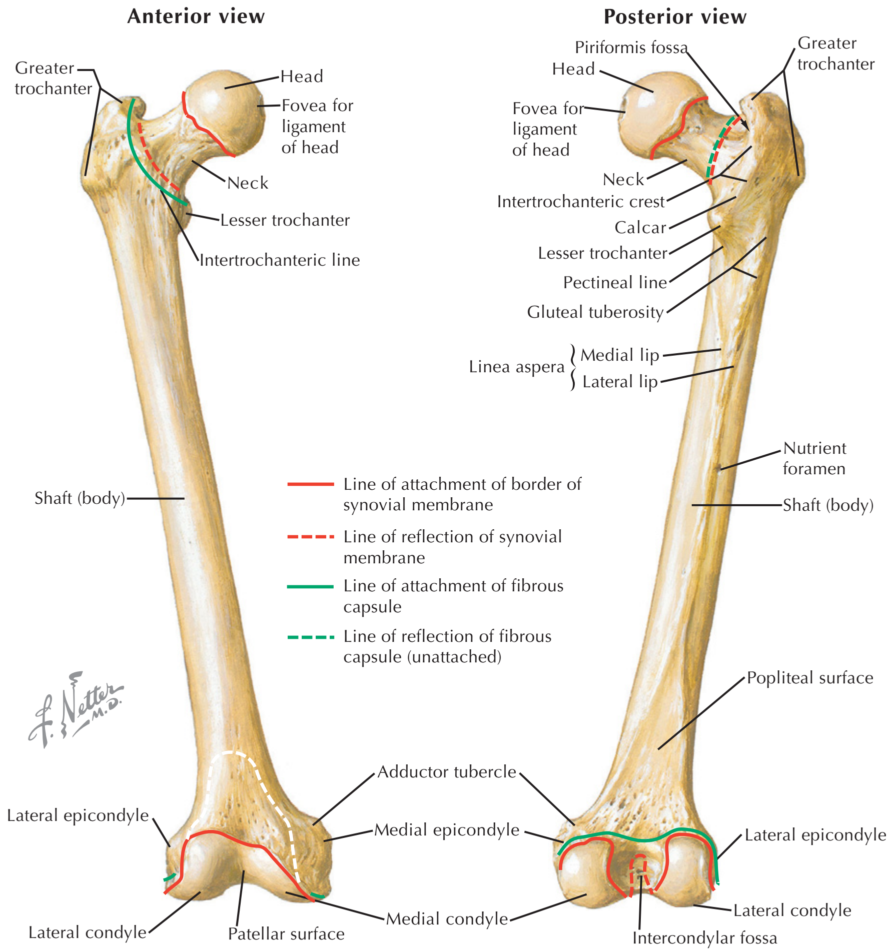

Anterior view
Iliac crest
Anterior superior iliac spine
Tensor fasciae latae muscle
Vastus lateralis muscle
Rectus femoris muscle
Rectus femoris tendon (becoming part of quadriceps femoris tendon)
Iliotibial tract
Patella
Patellar ligament
Inguinal ligament
Hip joint
Sartorius muscle
Great saphenous vein
Vastus medialis muscle
Posterior view
Iliac crest
Gluteus medius muscle
Gluteus maximus muscle
Greater trochanter of femur
Ischial tuberosity
Gluteal fold
Iliotibial tract
Semitendinosus muscle
Adductor magnus muscle
Bicep femoris muscle
Long head
Short head
Gracilis tendon
Great saphenous vein
Popliteal fossa

STRUCTURE	CLINICAL APPLICATION
Iliac crest	Site for "hip pointers"/contusion of lilac crest Common site for autologous bone graft harvest
Greater trochanter	Tenderness can indicate trochanteric bursitis.
Ischial tuberosity	Avulsion fracture (hamstrings) or bursitis can occur here.
Iliotibial tract (band)	Can snap over greater trochanter of femur, creating "snapping hip" syndrome. Tightness can cause lateral knee and/or thigh pain.
Quadriceps muscle • Vastus lateralis • Vastus medialis • Rectus femoris • Vastus intermedius (not shown)	Atrophy can indicate an injury and/or contribute to knee pain.
Quadriceps tendon	Can rupture with eccentric loading. Defect is felt here.
Popliteal fossa	Popliteal artery pulse can be palpated here.


Anterior view
Greater trochanter
Head
Fovea for ligament of head
Neck
Lesser trochanter
Intertrochanteric line
Shaft (body)
Lateral epicondyle
Lateral condyle
Patellar surface
Adductor tubercle
Medial epicondyle
Medial condyle
Posterior view
Piriformis fossa
Head
Greater trochanter
Fovea for ligament of head
Neck
Intertrochanteric crest
Calcar
Lesser trochanter
Pectineal line
Gluteal tuberosity
Linea aspera
Medial lip
Lateral lip
Nutrient foramen
Shaft (body)
Popliteal surface
Lateral epicondyle
Lateral condyle
Intercondylar fossa
Line of attachment of border of synovial membrane
Line of reflection of synovial membrane
Line of attachment of fibrous capsule
Line of reflection of fibrous capsule (unattached)
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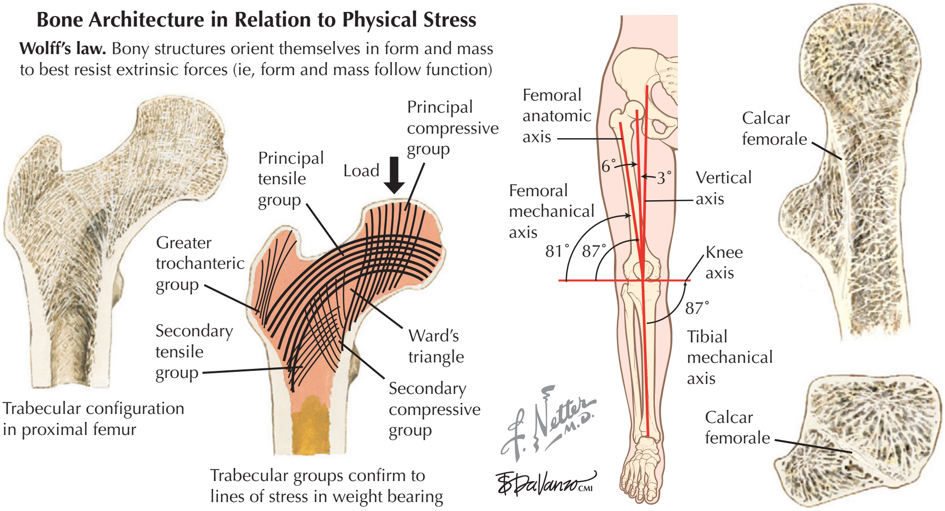
CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
FEMUR				
• Long bone characteristics • Proximal femur ∘ Head: nearly spherical (⅔) ∘ Neck: anteverted from shaft ∘ Greater trochanter: lateral ∘ Lesser trochanter: posteromedial • Shaft: tubular, bows anteriorly ∘ Linea aspera posterior: insertion of fascia and muscles • Distal femur: 2 condyles ∘ Medial: larger, more posterior ∘ Lateral: more anterior & proximal ∘ Trochlea: anterior articular depression between condyles	**Primary** (Shaft) **Secondary** Distal physis Head Gtr troch Lsr troch	7-8wk (fetal) birth 1yr 4-5yr 10yr	16-18yr 19yr 18yr 16yr 16yr	• Blood supply ∘ Head/neck: primarily medial femoral circumflex artery (also lateral FCA and of ligamentum teres artery) ∘ Shaft: nutrient artery (from profunda fem.) • Head vascularity is susceptible to disruption in fracture or dislocation—leads to AVN • Proximal femur bone density decreases with age, making it more susceptible to fracture • Calcar femorale—vertically oriented dense bone in posteromedial aspect of prox. femur • Piriformis fossa—posteromedial base of gtr trochanter: starting point for femoral nails • Neck/shaft angle: 120-135° • Femoral anteversion: 10-15° • Distal femur physis: grows approx. 7mm/yr

Bone Architecture in Relation to Physical Stress

Wolff's law. Bony structures orient themselves in form and mass to best resist extrinsic forces (ie, form and mass follow function)


Principal compressive group
Principal tensile group
Load
Greater trochanteric group
Secondary tensile group
Ward's triangle
Secondary compressive group
Femoral anatomic axis
Femoral mechanical axis
6°
3°
81°
87°
Vertical axis
Knee axis
87°
Tibial mechanical axis
Calcar femorale
Calcar femorale
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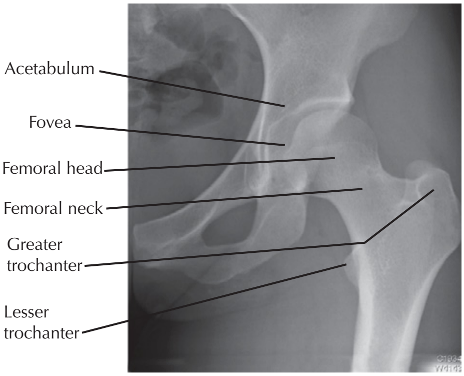
Trabecular configuration in proximal femur

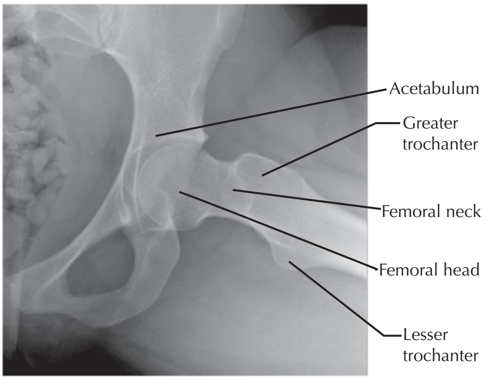
Trabecular groups confirm to lines of stress in weight bearing

GROUP	COMMENT
PROXIMAL FEMUR OSTEOLOGY	
• Proximal femur comprises several distinct trabecular bone groups that support the head and neck. • The presence or absence of these groups helps to determine the presence & degree of osteopenia in the prox. femur. • Malalignment of bone groups determines the fracture type in displaced femoral neck fractures.	
Primary compressive	From superior femoral head to medial neck, strongest cancellous bone, supports body weight
Primary tensile	From inferior femoral head to lateral cortex
Secondary compressive	Oriented along lines of stress in proximal femur
Secondary tensile	Oriented along lines of stress in lateral proximal femur
Greater trochanteric group	Oriented along lines of stress within the greater trochanter
Ward's triangle	Area of relative few trabeculae within the femoral neck

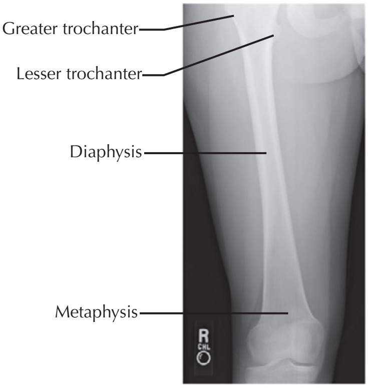
LOWER EXTREMITY ALIGNMENT	
Definitions	
Anatomic axis	Line drawn along the axis of the femur
Mechanical axis	Line drawn between center of femoral head and intercondylar notch
Knee axis	Line drawn along the inferior aspect of both femoral condyles
Vertical axis	Vertical line, perpendicular to the ground
Lateral femoral angle	Angle formed between the knee axis and the femoral axis
Relationships	
Knee axis	Parallel to the ground and perpendicular to vertical axis
Mechanical axis	Average of 6° from anatomic axis Approximately 3° from the vertical axis
Lateral femoral angle	81° with respect to femoral anatomic axis 87° with respect to femoral mechanical axis


Acetabulum
Fovea
Femoral head
Femoral neck
Greater trochanter
Lesser trochanter

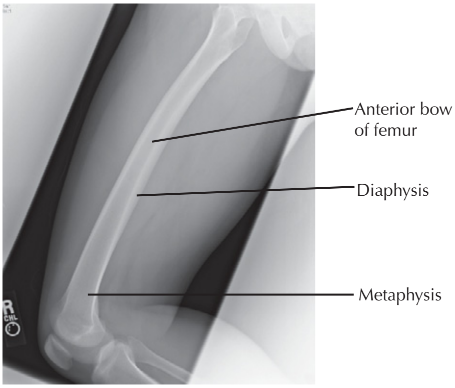
Hip, AP xray


Acetabulum
Greater trochanter
Femoral neck
Femoral head
Lesser trochanter

Hip, Lateral xray


Greater trochanter
Lesser trochanter
Diaphysis
Metaphysis
R

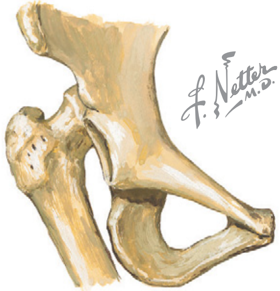
Femur, AP


Anterior bow of femur
Diaphysis
Metaphysis
R

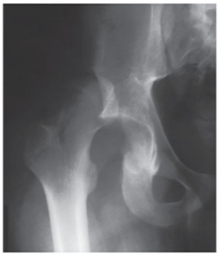
Femur, Lateral

RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
AP pelvis	Supine, beam at symphysis	Both hips and pelvis	Fractures, dislocations, arthritis
AP hip	Beam aimed at proximal femur	Femoral head, acetabulum	Fractures, arthritis
Lateral (frog leg)	Flex, abd. ER hip, beam at hip	Fem. neck, head, acetab. rim	Fractures, arthritis
Lateral (cross-table)	Flex contralateral hip to remove it; aim beam across table at hip	Femoral neck, head, acetabular rim. Ant & post. cortices seen well on lateral	Often needed for preop fx films Used intraop (fluoro) for ORIF
AP femur	Supine, beam at mid femur	Femur, soft tissues	Fractures, tumors
Lateral femur	Beam laterally at mid femur	Femur, soft tissues	Fractures, tumors
See Chapter 7, Pelvis, for views of acetabulum.			
		OTHER STUDIES	
CT	Axial, coronal, & sagittal views	Articular congruity, fracture fragments	Intraarticular acetabulum or neck fractures
MRI	Sequence protocols vary	Labrum, cartilage, cancellous bone	Labral tears, AVN, stress fractures
Bone scan	Radioisotope	All bones evaluated	Stress fractures, infection, tumor

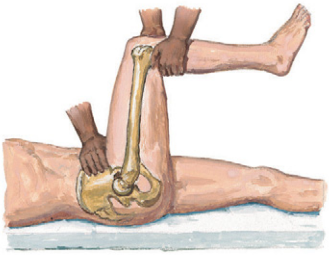
Posterior Dislocation



Anteroposterior view. Dislocated femoral head lies posterior and superior to acetabulum. Femur adducted and internally rotated; hip flexed. Sciatic nerve may be stretched

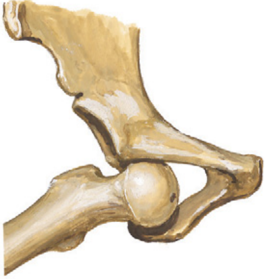


Anteroposterior radiograph shows posterior dislocation

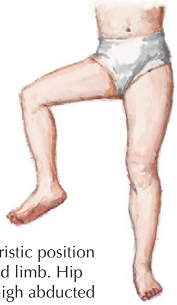


Allis maneuver. Patient supine on table, under anesthesia or sedation. Examiner applies firm distal traction at flexed knee to pull head into acetabulum; slight rotary motion may also help. Assistant fixes pelvis by pressing on anterior superior iliac spines

Anterior Dislocation

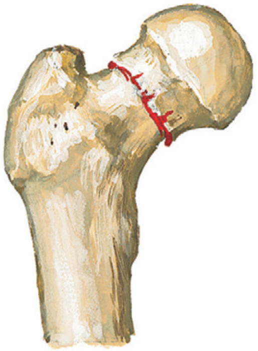


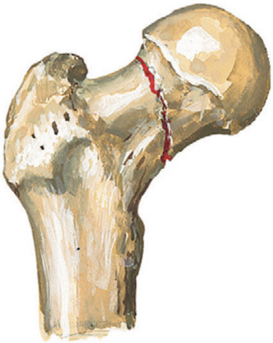
Anterior view. Femoral head in obturator foramen of pelvis; hip flexed and femur widely abducted and externally rotated

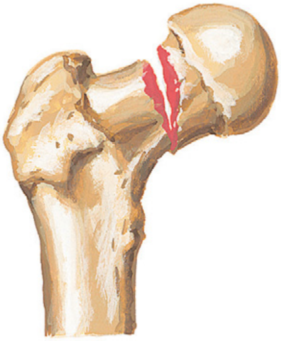


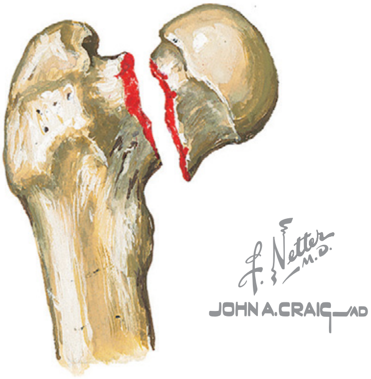
Characteristic position of affected limb. Hip flexed, thigh abducted and externally rotated.

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
HIP DISLOCATION			
• High-energy trauma (esp. MVA, dashboard injury) or significant fall • Orthopaedic emergency; risk of femoral head AVN increases with late/delayed reduction • Multiple associated injuries +/− fractures (e.g., femoral head/neck, acetabulum) • Posterior most common (85%)	**Hx:** Trauma, severe pain, cannot move thigh/hip **PE:** Thigh position: • Post.: adducted, flexed, IR • Ant.: abducted, flexed, ER • Pain (esp. with motion), good neurovascular exam (sciatic n.) **XR:** AP pelvis, frog lateral (femoral head appears of different size), femur and knee series **CT:** R/o fx or bony fragments/ loose bodies (postreduction)	**Posterior: Thompson:** I: No or minor post. wall fx II: Large posterior wall fx III: Comminuted acetabular fx IV: Acetabular floor fx V: Femoral head fx **Anterior: Epstein:** I (A, B, C): Superior II (A, B, C): Inferior A: No associated fx B: Femoral head fx C: Acetabular fx	Early reduction essential (<6 hr), then repeat XR & neuro exam **Posterior:** I: Closed reduction and abduction pillow II-V: 1. Closed reduction (open if irreducible) 2. ORIF(fracture or excise fragment/LB) **Anterior:** Closed reduction, ORIF if necessary
COMPLICATIONS: Posttraumatic osteonecrosis (AVN) (reduced risk with early reduction); sciatic nerve injury (posterior dislocations); femoral artery/nerve injury (anterior dislocations); osteoarthritis; heterotopic ossification			


Type I. Impacted fracture


Type II. Nondisplaced fracture

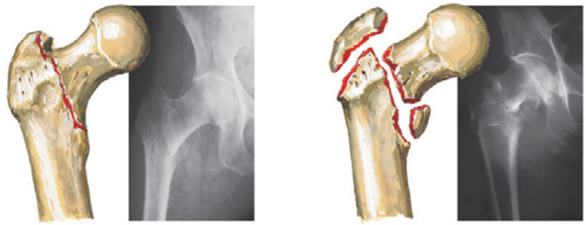

Type III. Partially displaced



Type IV. Displaced fracture. vertical fracture line generally suggests poorer prognosis

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
FEMORAL NECK FRACTURE			
• Mechanism ∘ Fall by elderly person most common ∘ High-energy injury in young adults (e.g., MVA) • Intracapsular fractures • Femoral head vascularity at risk in displaced fractures • Associated with osteoporosis • High morbidity & complication rates	**Hx:** Fall, pain, inability to bear weight/walk **PE:** LE shortened, abducted, externally rotated. Pain w/"rolling"/log roll extremity **XR:** AP pelvis, cross-table lateral **MR:** If symptomatic with negative XR (i.e., rule out occult fracture)	**Garden (4 types):** I: Incomplete fracture; valgus impaction II: Complete fracture; nondisplaced III: Complete fracture, partial displacement (varus) IV: Complete fracture, total displacement	**Young (high-energy)** • Urgent reduction (CR vs OR) • ORIF (3 parallel screws) **Elderly** • Early medical evaluation • Types I & II: ORIF (3 screws) • Types III & IV: hemiarthroplasty • Medically unstable, nonoperative
COMPLICATIONS: Osteonecrosis (AVN): incidence increases with fx type (displacement) +/− late segmental collapse; nonunion; hardware failure			

Intertrochanteric Fracture of Femur



I. Nondisplaced fracture

III. Comminuted displaced fracture

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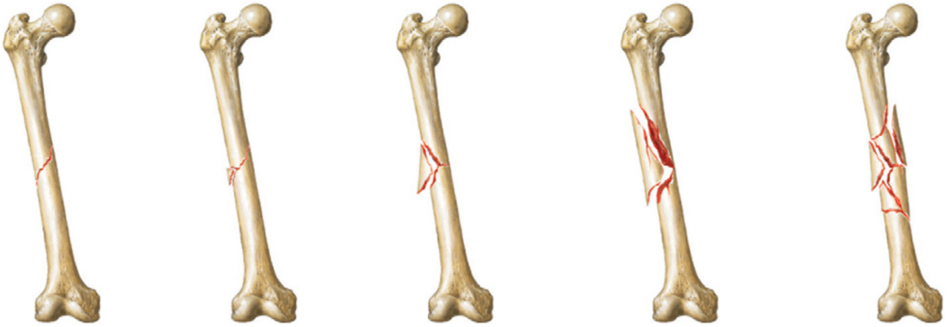
DaVanzo

Femoral Shaft Fractures



O Comminution

I Small cortical discontinuity

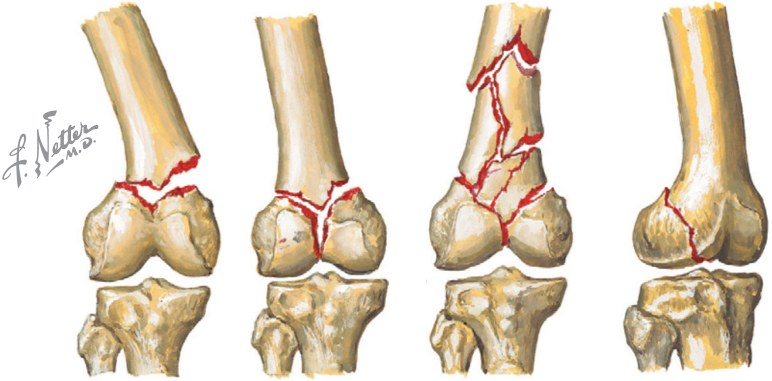
II Butterfly 50% contact of cortex

III Large butterfly (zero rotational control)

IV Severe comminution

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
INTERTROCHANTERIC FRACTURE			
• Fall by an elderly person most common • Assoc. w/osteoporosis • Occurs along or below intertrochanteric line • Extracapsular fractures • Stable vascularity • Most heal well with proper fixation	**Hx:** Fall, pain, inability to bear weight/walk **PE:** LE shortened, ER. Pain w/"log rolling" of leg **XR:** AP pelvis/hip cross-table **MR:** If symptomatic with negative XR (r/o occult fracture)	**Evans/Jensen:** • Type IA: Nondisplaced • Type IB: 2 part displaced • Type IIA: 3 part, GT fragment • Type IIB: 3 part, LT fragment • Type III: 4 part **Reverse obliquity**	• Early medical evaluation • Early (<48hr) ORIF ◦ Sliding hip screw/plate ◦ Cephalomedullary nail • Reverse obliquity ◦ Blade plate ◦ Cephalomedullary nail • Nonoperative; medically unstable patient
COMPLICATIONS: Nonunion/malunion, decr. ambulatory status, hardware failure, mortality (20% in 1st 6 mo)			
FEMORAL SHAFT FRACTURE			
• Orthopaedic emergency • High-energy injury (e.g., MVA, fall) • Associated injuries (common) • Potential source of significant blood loss • Compartment syndrome can occur • Transport patient in traction	**Hx:** Trauma, pain, swelling deformity, inability to walk/bear weight **PE:** Deformity, +/− open wound & soft tissue injury; check distal pulses **XR:** AP/lateral femur; Knee: trauma series Hip: r/o ipsilateral femoral neck fx	**Winquist/Hansen (5 types):** *Stable* 0: No comminution I: Minimal comminution II: Comminuted: >50% of cortices intact *Unstable* III: Comminuted: <50% of cortices intact IV: Complete comminution, no intact cortex	**Operative: within 24hr** • Antegrade, reamed, locked IM nail • Retrograde nail if needed • External fixation ◦ Medically unstable ◦ High-grade open fx **Traction**—if surgery delayed, medically unstable patient
COMPLICATIONS: Neurovascular injury/hemorrhagic shock, nonunion/malunion, hardware failure, knee injury (5%)			

Distal Femur Fracture



Transverse supracondylar fracture

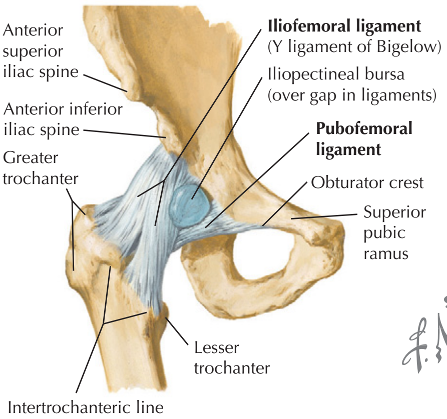
Intercondylar (T or Y) fracture

Comminuted fracture extending into shaft

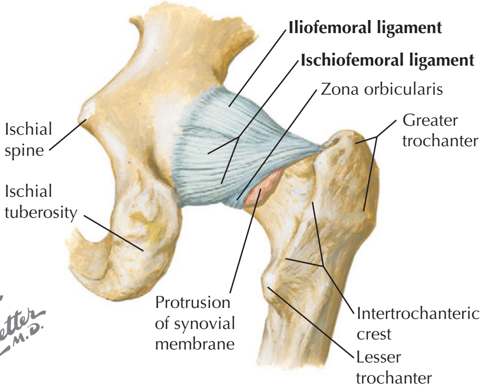
Fracture of single condyle (may occur in frontal or oblique plane)

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
SUBTROCHANTERIC FRACTURE			
• Within 5cm of lesser trochanter (LT) • Mechanism: ◦ Low-energy fall: elderly, pathologic fx ◦ High-energy: younger (e.g., MVA) • Vascularity is tenuous, can compromise healing • Rule out pathologic fx if fracture occurs with minimal/no trauma • High biomechanical stresses	**Hx:** Trauma, pain, inability to bear weight **PE:** Shortened, rotated LE. No ROM (pain), check neurovascular status **XR:** AP & lateral of femur. Also, AP pelvis, hip (AP & cross-table lateral), & knee series **CT:** Usually not needed	**Russell-Taylor:** Type I: no piriformis fossa extension/involvement A: intact LT B: detached LT Type II: fracture involves piriformis fossa A: intact LT B: detached LT	**By type:** IA: standard IM nail IB: cephalomedullary nail IIA: cephalomedullary nail with trochanteric start point IIB: 95° blade plate or cephalomedullary nail with trochanteric start point
COMPLICATIONS: Nonunion, malunion, loss of fixation/implant failure, loss of some ambulatory function (esp. in elderly)			
DISTAL FEMUR FRACTURE			
• Mechanism: direct impact ◦ Young: high energy ◦ Elderly: low energy (fall) • Articular congruity needed for normal knee function • Many associated injuries (e.g., tibia fx, knee ligament injury) • Vascular injuries possible • Quads/hamstrings: shorten fx. Gastroc: displace fx posteriorly	**Hx:** Trauma, pain, inability to bear weight **PE:** Swollen, +/− gross deformity. Careful pulse evaluation (Doppler exam if needed) **XR:** AP & lateral knee, femur, tibia **CT:** Evaluate intraarticular involvement & preop plan	**AO/Muller:** A: Extraarticular subtypes 1, 2, 3 B: Unicondylar subtypes 1, 2, 3 C. Bicondylar subtypes 1, 2, 3	• Nondisplaced/stable: ◦ Cast, immobilizer, brace • Displaced/unstable: ◦ Extraarticular: plate or nail ◦ Intraarticular: anatomic reduction of articular surface & locking plate/blade plate • External fixation: temporarily in open fx, severely swollen soft tissues, unstable patient
COMPLICATIONS: Posttraumatic arthritis, nonunion/malunion, knee stiffness/loss of ROM			

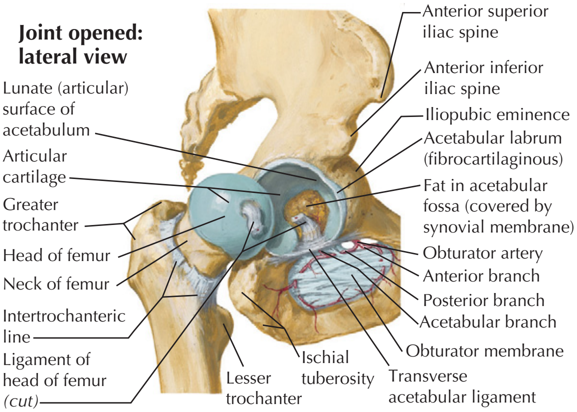
Anterior view

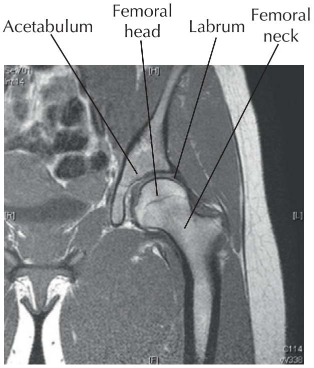

Anterior superior iliac spine
Anterior inferior iliac spine
Greater trochanter
Intertrochanteric line
Iliofemoral ligament
(Y ligament of Bigelow)
Iliopectineal bursa
(over gap in ligaments)
Pubofemoral ligament
Obturator crest
Superior pubic ramus
Lesser trochanter

Posterior view


Iliofemoral ligament
Ischiofemoral ligament
Zona orbicularis
Greater trochanter
Ischial spine
Ischial tuberosity
Protrusion of synovial membrane
Intertrochanteric crest
Lesser trochanter

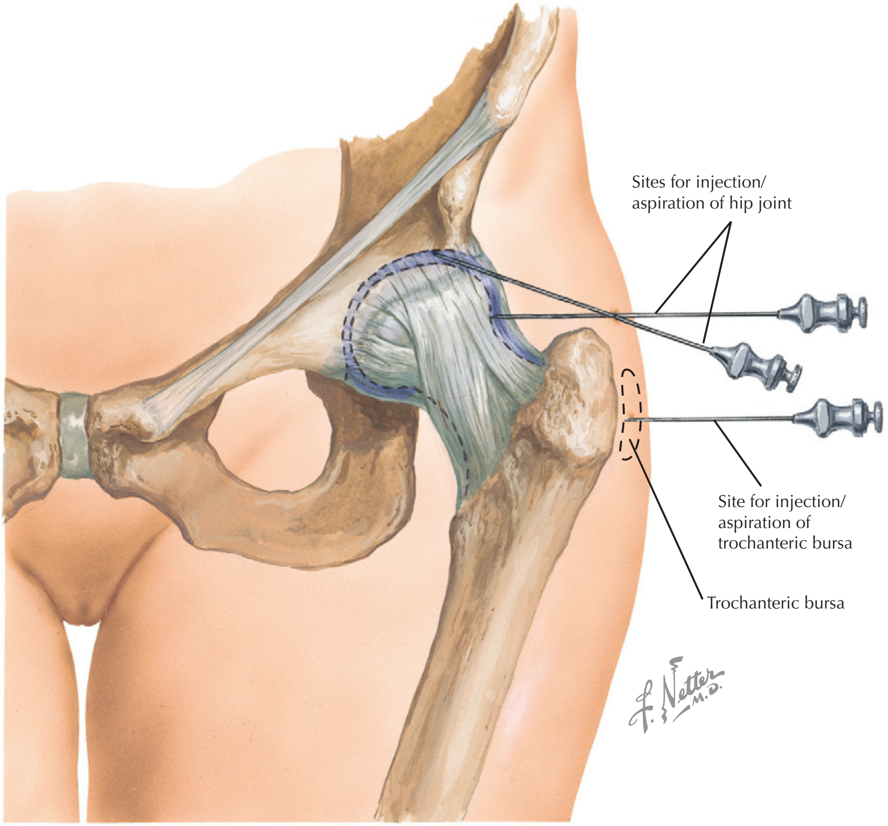
Joint opened: lateral view


Lunate (articular) surface of acetabulum
Articular cartilage
Greater trochanter
Head of femur
Neck of femur
Intertrochanteric line
Ligament of head of femur (cut)
Lesser trochanter
Ischial tuberosity
Anterior superior iliac spine
Anterior inferior iliac spine
Iliopubic eminence
Acetabular labrum (fibrocartilaginous)
Fat in acetabular fossa (covered by synovial membrane)
Obturator artery
Anterior branch
Posterior branch
Acetabular branch
Obturator membrane
Transverse acetabular ligament


Acetabulum
Femoral head
Labrum
Femoral neck

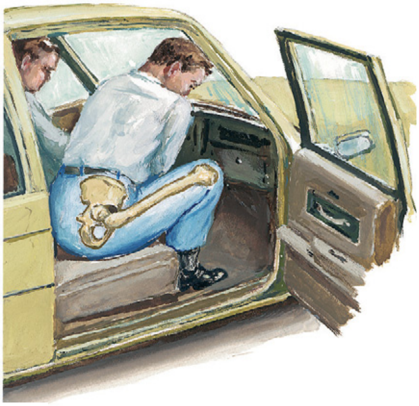
MRI, Hip: coronal

LIGAMENTS	ATTACHMENTS	COMMENTS
HIP		
• The hip is a spheroidal (ball & socket) joint. It has intrinsic stability from osseous, ligamentous, & muscular structures.		
Labrum	Along acetabular rim except inferiorly	Deepens socket, increases femoral head coverage; can be torn (cause of hip pain)
Transverse acetabular	Anteroinferior to posteroinferior acetabulum	Covers cotyloid notch in inferior central acetabulum
Ligamentum teres	Fovea (femoral head) to cotyloid notch	Small artery to femoral head within this ligament
Capsule ◦ Iliofemoral (2 bands) ◦ Pubofemoral ◦ Ischiofemoral	Acetabulum to femoral neck Superior: ASIS/ilium to greater trochanter Inferior: Ilium to intertrochanteric line/LT Anterior pubic ramus to intertroch. line Posterior acetabulum to superior femoral neck	Has some discrete thickenings (ligaments) Aka "Y ligament of Bigelow"; provides strong anterior support, resists extension Prevents hyperextension of hip, inferior joint support Broad, relatively weak ligament (minimal posterior support). Does not provide complete post. joint coverage, so lateral post. neck is extracapsular



STEPS
HIP INJECTION/ASPIRATION
1. Ask patient about allergies 2. Place patient supine, palpate the greater trochanter 3. Prep skin over insertion site (iodine/antiseptic soap) 4. Anesthetize skin locally (quarter size spot) 5. **Anterior:** Find the point of intersection b/w a vertical line below ASIS and horizontal line from greater trochanter. Insert 20-gauge (3in) spinal needle upward/slightly medial direction at that point. **Lateral:** Insert a 20-gauge (3in) spinal needle superior and medial to greater trochanter until it hits the bone (the needle should be within the capsule, which extends down the femoral neck). Can "walk" needle up neck into joint. 6. Inject (or aspirate) local or local/steroid preparation into joint. (The fluid should flow easily if needle is in joint.) 7. Dress injection site
TROCHANTERIC BURSA INJECTION
1. Ask patient about allergies 2. Place patient in lateral decubitus position, palpate the greater trochanter 3. Prep skin over lateral thigh (iodine/antiseptic soap) 4. Insert 20-gauge needle (at least 1½ in; 3in in larger patients) into thigh to the bone at the point of most tenderness. Withdraw needle (1-2mm) so it is just off the bone and in the bursa. Aspirate to ensure needle is not in a vessel. 5. Inject local or local/corticosteroid preparation into bursa. May redirect needle slightly to inject a septated bursa 6. Dress injection site

Osteoarthritis
Characteristic habitus and gait

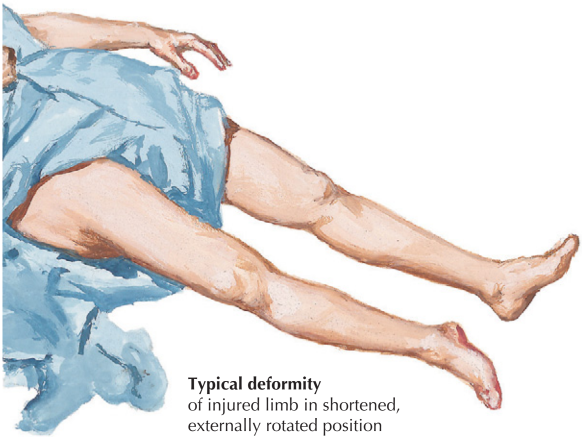


Trauma
Mechanism of injury often by impact with dashboard, which drives femoral head backward, out of acetabulum

LFCN entrapment
Numbness and dysesthesias in lateral thigh

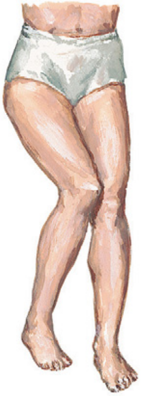
QUESTION	ANSWER	CLINICAL APPLICATION
1. Age	Young	Trauma, developmental disorders
	Middle age–elderly	Arthritis, fractures
2. Pain		
a. Onset	Acute	Trauma, (fracture, dislocation), infection
	Chronic	Arthritis, labral tear
b. Location	Lateral hip/thigh	Bursitis, LFCN entrapment, snapping hip syndrome
	Buttocks/posterior thigh	Consider spine etiology
	Groin/medial thigh	Hip joint or acetabular etiology (likely not from spine)
	Anterior thigh	Proximal femur pathology
c. Occurrence	Ambulation/WB/motion	Hip joint etiology (i.e., not pelvis/spine)
	At night	Tumor, infection
3. Snapping	With ambulation	Snapping hip syndrome, loose bodies, arthritis
4. Assisted ambulation	Cane/crutch/walker	Use (and frequency) indicates severity of pain and condition
5. Activity tolerance	Walk distance and activity cessation	Less distance walked and fewer activities no longer performed = more severe
6. Trauma	Fall, MVA	Fracture, dislocation, labral tear
7. Activity/work	Repetitive use	Femoral stress fracture
8. Neurologic symptoms	Pain, numbness, tingling	LFCN entrapment, spine etiology (e.g., radiculopathy)
9. History of arthritides	Multiple joints involved	Systemic inflammatory disease

Femoral neck fracture



Typical deformity
of injured limb in shortened,
externally rotated position

Posterior hip dislocation



Typical deformity
injured limb
adducted, internally
rotated and flexed
at hip and knee,
with knee resting
on opposite thigh

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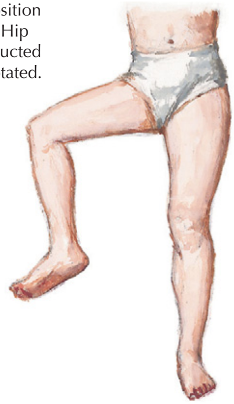
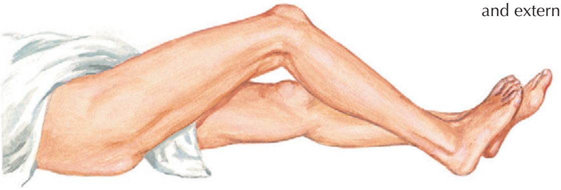
Anterior hip dislocation

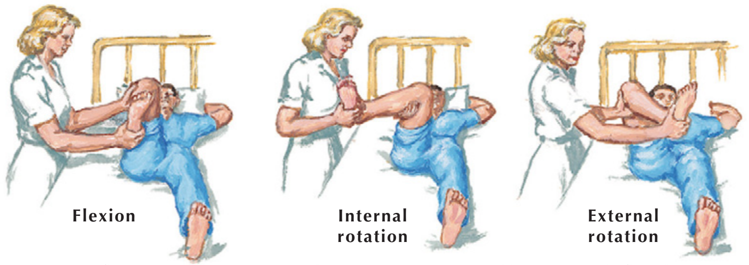
Characteristic position
of affected limb. Hip
flexed, thigh abducted
and externally rotated.





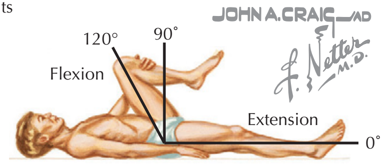
Flexion contracture of hip joint

EXAM/OBSERVATION	TECHNIQUE	CLINICAL APPLICATION
	INSPECTION	
Skin	Discoloration, wounds Gross deformity	Trauma Fracture, dislocation
Position	Shortened, ER Adducted, IR Abducted, ER Flexed	Femoral neck fracture; intertrochanteric fracture Posterior dislocation Anterior dislocation Hip flexion contracture
Gait		
Antalgic (painful)	Decreased stance phase	Knee, ankle, heel (spur), midfoot, toe pain
Lurch (Trendelenburg)	Lean laterally (on WB side)	Gluteus medius weakness
Lurch	Lean posteriorly (keep hip ext)	Gluteus maximus weakness
	PALPATION	
Bony structures	Greater trochanter/bursa	Pain/palpable bursa: infection/bursitis, gluteus medius tendinitis Snapping—IT band may snap over GT
	Lesser trochanter	Snapping— Psoas tendon may snap over LT

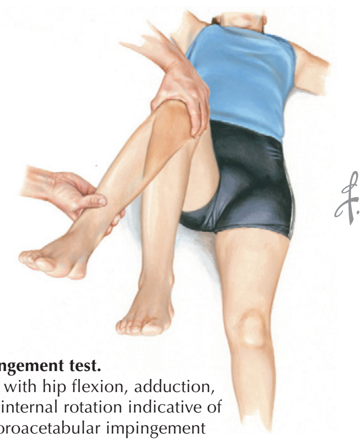


Hip flexion-rotation exercises with patient supine. Hip and knee passively flexed, then limb rotated laterally and medially as pain permits

Internal rotation
Limitation of internal rotation of left hip. Hip rotation best assessed with patient in prone position because any restriction can be detected and measured easily

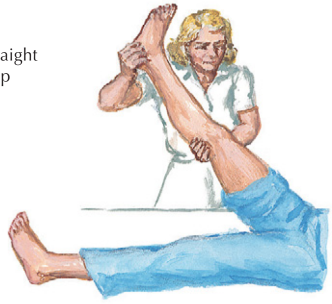


EXAM/OBSERVATION	TECHNIQUE	CLINICAL APPLICATION
RANGE OF MOTION		
Flexion	Supine: knee to chest Thomas test	Normal: 120-135° Rule out flexion contracture (see Special Tests, p. 263)
Extension	Prone: lift leg off table	Normal: 20-30°
Abduction/adduction	Supine: leg lateral/medial	Normal: Abd: 40-50°, Add: 20-30°
Internal/external rotation	Seated: foot lateral/medial Prone: flex knee leg in/out	Normal: IR: 30°, ER: 50° Normal: IR: 30°, ER: 50°
NEUROVASCULAR		
Sensory		
Genitofemoral nerve (L1-2)	Proximal anteromedial thigh	Deficit indicates corresponding nerve/root lesion
Obturator nerve (L2-4)	Inferomedial thigh	Deficit indicates corresponding nerve/root lesion
Lat. femoral cutaneous n. (L2-3)	Lateral thigh	Deficit indicates corresponding nerve/root lesion
Femoral nerve	Anteromedial thigh	Deficit indicates corresponding nerve/root lesion
Post. femoral cutaneous n. (S1-3)	Posterior thigh	Deficit indicates corresponding nerve/root lesion
Motor		
Obturator nerve (L2-4)	Thigh/hip adduction	Weakness = adductor muscle group or nerve/root lesion
Superior gluteal nerve L5)	Thigh abduction	Weakness = gluteus medius or nerve/root lesion
Femoral nerve (L2-4)	Hip flexion Knee extension	Weakness = iliopsoas or nerve/root lesion Weakness = quadriceps or nerve/root lesion
Inferior gluteal nerve (L5-S2)	Hip extension	Weakness = gluteus maximus or nerve/root lesion
Sciatic: Tibial portion (L4-S3) Peroneal portion (L4-S2)	 Knee flexion Knee flexion	 Weakness = biceps long head or nerve/root lesion Weakness = biceps short head or nerve/root lesion
Other		
Reflex	None	
Pulses	Femoral	



Inpingement test. Pain with hip flexion, adduction, and internal rotation indicative of femoroacetabular impingement and for early arthritis.

Stinchfield test. Pain with resisted straight leg raise indicates hip joint pathology.



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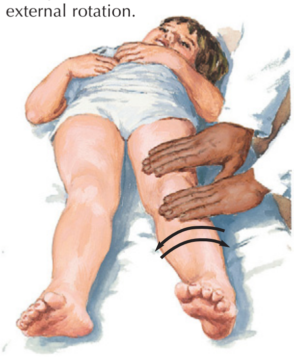
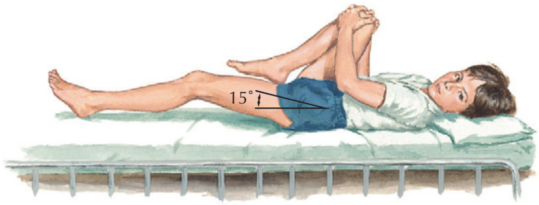
Log roll test. Examiner places hands on limb, gently rolls hip into internal and external rotation.

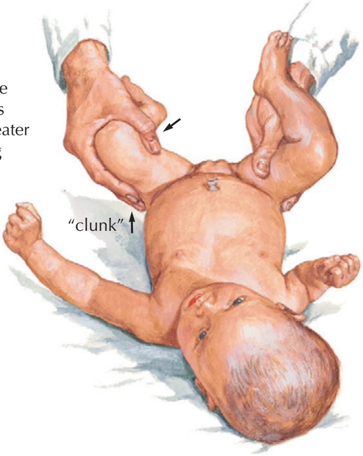


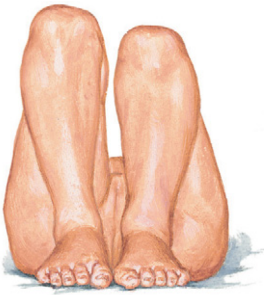


Thomas' sign Hip flexion contracture determined with patient supine. Unaffected hip flexed only until lumbar spine is flat against examining table. Affected hip cannot be fully extended, and angle of flexion is recorded.

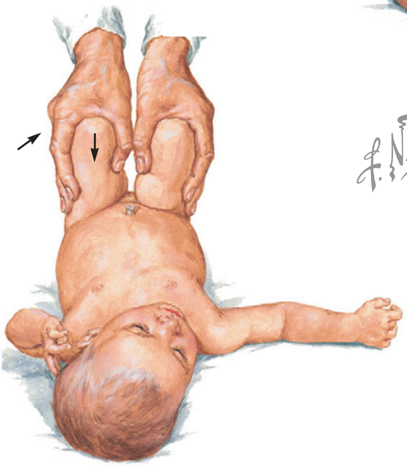
EXAM/OBSERVATION	TECHNIQUE	CLINICAL APPLICATION
	SPECIAL TESTS	
Impingement	Supine: flex, adduct, IR hip	Pain may be indicative of femoral acetabular impingement.
FABER/Patrick	**F**lex, **AB**duct, **ER** hip, then abduct more (figure of 4)	Positive if painful. SI joint or hip pathology.
Log roll	Supine, hip extended: IR/ER	Pain in hip is consistent with arthritis.
Stinchfield	Resisted straight leg raise	Pain is positive test for hip pathology.
Thomas sign	Supine; one knee to chest	If opposite thigh elevates off table, flexion contracture.
Ober	On side: flex and abduct hip	Extend and adduct hip; if stays in abduction, ITB contracture.
Piriformis	On side: adduct hip	Pain in hip/pelvis indicates tight piriformis (compressing sciatic nerve).
90-90 straight leg	Flex hip & knee 90°, extend knee	>20° of flexion after full knee extension = tight hamstrings.
Ely's	Prone: passively flex knee	If hip flexes as knee is flexed, tight rectus femoris muscle.
Leg length	ASIS to medial malleolus	A measured difference of >1cm is positive.
Meralgia	Pressure medial to ASIS	Reproduction to pain, burning, numbness = LFCN entrapment.
See Chapter 7, Pelvis, for Trendelenburg test.		

Ortolani's (reduction) test
With baby relaxed and content on firm surface, hips and knees flexed to 90°. Hips examined one at a time. Examiner grasps baby's thigh with middle finger over greater trochanter and lifts thigh to bring femoral head from its dislocated posterior position to opposite the acetabulum. Simultaneously, thigh gently abducted, reducing femoral head into acetabulum. In positive finding, examiner senses reduction by palpable, nearly audible "clunk"





Allis' or Galeazzi's sign
With knees and hips flexed, knee on affected side lower because femoral head lies posterior to acetabulum in this position



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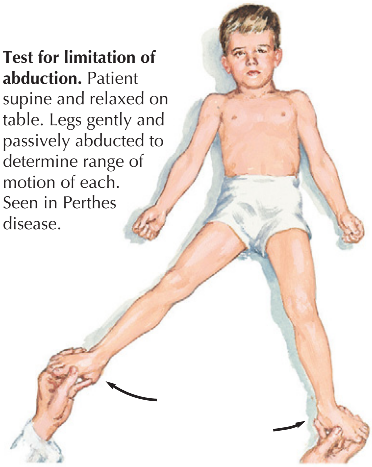
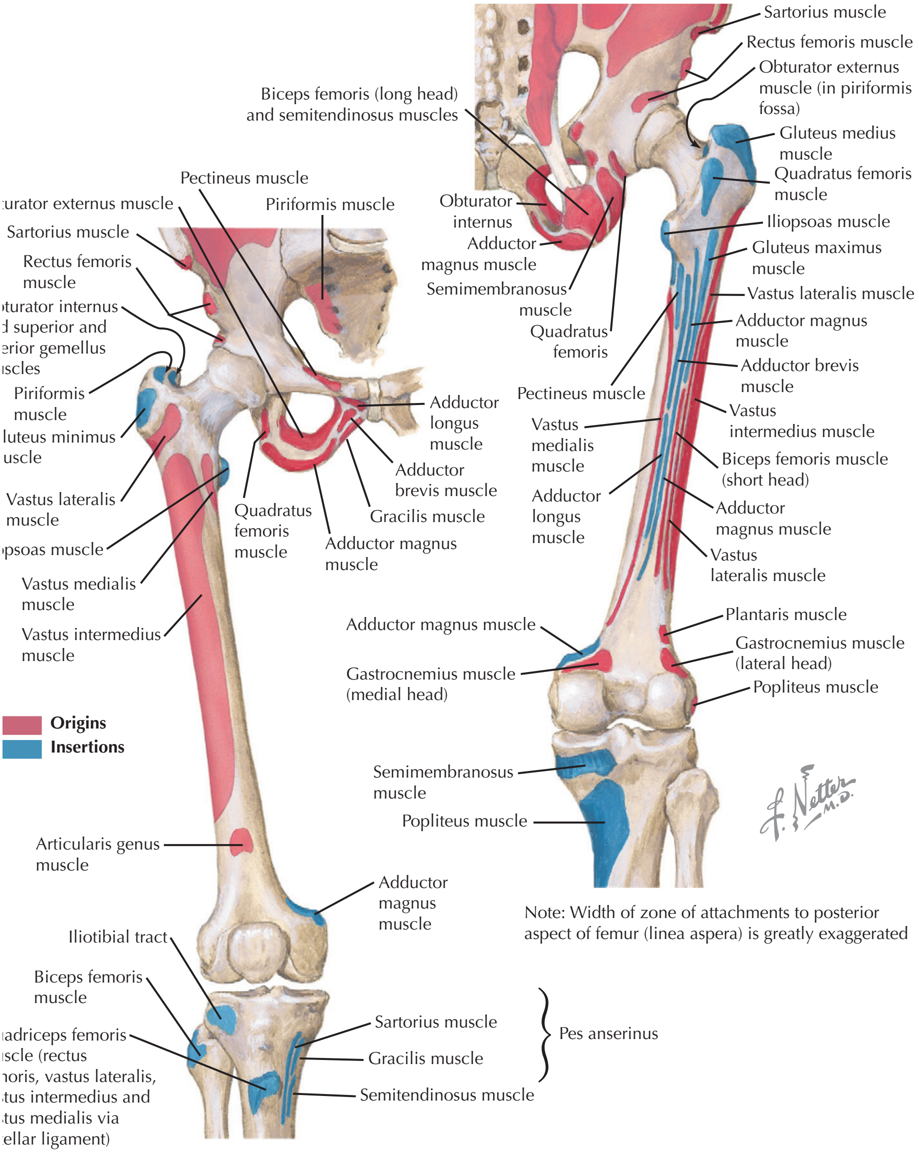
Barlow's (dislocation) test
Reverse of Ortolani's test. If femoral head is in acetabulum at time of examination, Barlow's test is performed to discover any hip instability. Baby's thigh grasped as above and adducted with gentle downward pressure. Dislocation is palpable as femoral head slips out of acetabulum. Diagnosis confirmed with Ortolani's test

Test for limitation of abduction. Patient supine and relaxed on table. Legs gently and passively abducted to determine range of motion of each. Seen in Perthes disease.



EXAM/OBSERVATION	TECHNIQUE	CLINICAL APPLICATION
	SPECIAL TESTS	
Ortolani (peds)	Hips at 90°, abduct hips	A clunk indicates the hip(s) was dislocated and now reduced
Barlow (peds)	Hips at 90°, posterior force	A clunk indicates the hip(s) is now dislocated, should reduce with Ortolani
Galeazzi (peds)	Supine: flex hips & knees	Any discrepancy in knee height: 1. Dislocated hip, 2. Short femur


Biceps femoris (long head) and semitendinosus muscles
Pectineus muscle
urator externus muscle
Piriformis muscle
Sartorius muscle
Rectus femoris muscle
turator internus
d superior and
erior gemellus
scles
Piriformis muscle
luteus minimus
uscle
Vastus lateralis muscle
psoas muscle
Vastus medialis muscle
Vastus intermedius muscle
Obturator internus
Adductor magnus muscle
Semimembranosus muscle
Quadratus femoris
Adductor longus muscle
Adductor brevis muscle
Gracilis muscle
Quadratus femoris muscle
Adductor magnus muscle
Pectineus muscle
Vastus medialis muscle
Adductor longus muscle
Sartorius muscle
Rectus femoris muscle
Obturator externus muscle (in piriformis fossa)
Gluteus medius muscle
Quadratus femoris muscle
Iliopsoas muscle
Gluteus maximus muscle
Vastus lateralis muscle
Adductor magnus muscle
Adductor brevis muscle
Vastus intermedius muscle
Biceps femoris muscle (short head)
Adductor magnus muscle
Vastus lateralis muscle
Adductor magnus muscle
Gastrocnemius muscle (medial head)
Plantaris muscle
Gastrocnemius muscle (lateral head)
Popliteus muscle
Semimembranosus muscle
Popliteus muscle
🟥 Origins
🟦 Insertions
Articularis genus muscle
Adductor magnus muscle
Iliotibial tract
Biceps femoris muscle
adriceps femoris
scle (rectus
oris, vastus lateralis,
tus intermedius and
tus medialis via
ellar ligament)
Sartorius muscle
Gracilis muscle
Semitendinosus muscle
Pes anserinus
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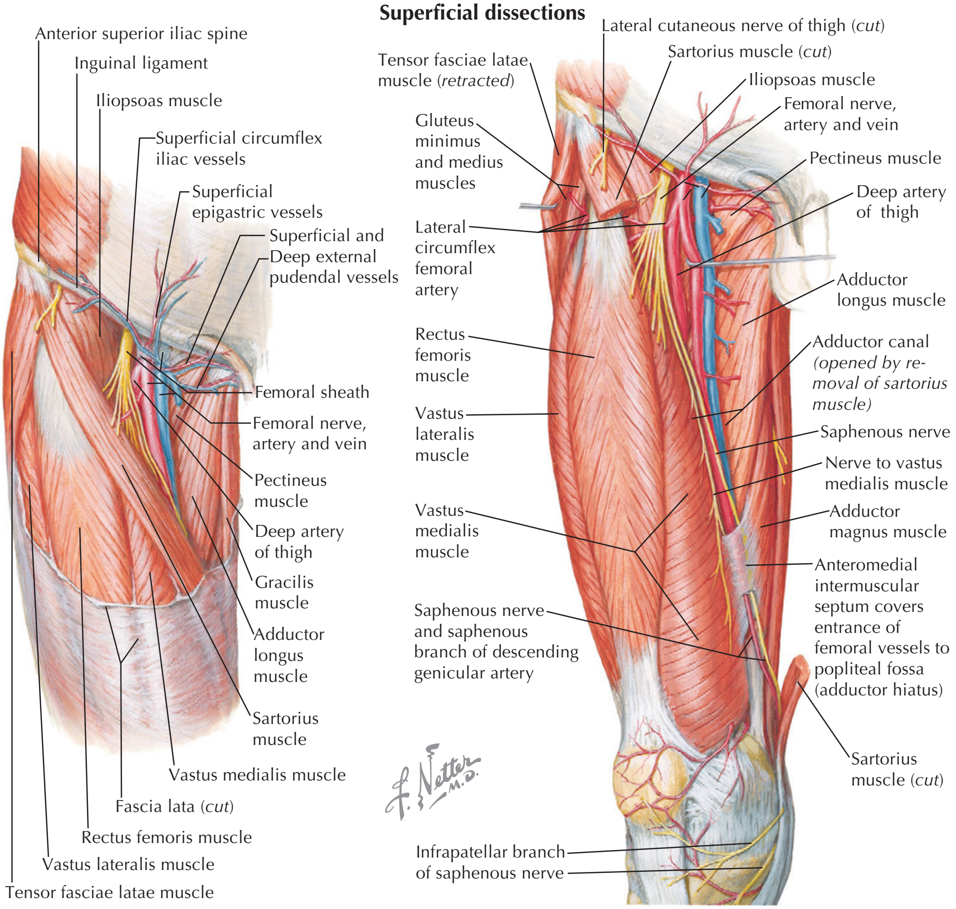
Note: Width of zone of attachments to posterior aspect of femur (linea aspera) is greatly exaggerated

PUBIC RAMI (ASPECT)	GREATER TROCHANTER	ISCHIAL TUBEROSITY	LINEA ASPERA/ POSTERIOR FEMUR
Pectineus (pectineal line/sup)	Piriformis (anterior)	Inferior gemellus	Adductor magnus*
Adductor magnus (inferior)	Obturator internus (anterior)	Quadratus femoris	Adductor longus
Adductor longus (anterior)	Superior gemellus	Semimembranosus	Adductor brevis
Adductor brevis (inferior)	Gluteus medius (posterior)	Semitendinosus	Biceps femoris (SH)
Gracilis (inferior)	Gluteus minimus (anterior)	Biceps femoris (LH)	Pectineus
Psoas minor (superior)		Adductor magnus*	Gluteus maximus
			Vastus lateralis
			Vastus medialis

*Adductor magnus has two origins.

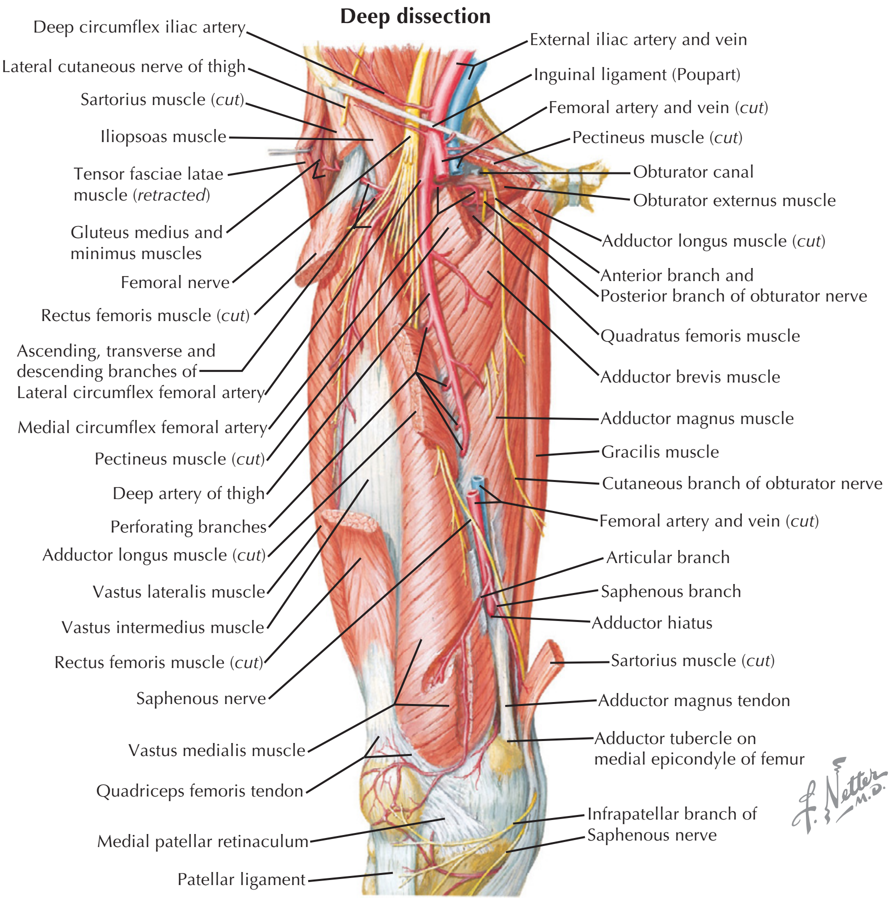


Superficial dissections

Anterior superior iliac spine
Inguinal ligament
Iliopsoas muscle
Superficial circumflex iliac vessels
Superficial epigastric vessels
Superficial and Deep external pudendal vessels
Femoral sheath
Femoral nerve, artery and vein
Pectineus muscle
Deep artery of thigh
Gracilis muscle
Adductor longus muscle
Sartorius muscle
Vastus medialis muscle
Fascia lata (cut)
Rectus femoris muscle
Vastus lateralis muscle
Tensor fasciae latae muscle
Tensor fasciae latae muscle (retracted)
Gluteus minimus and medius muscles
Lateral circumflex femoral artery
Rectus femoris muscle
Vastus lateralis muscle
Vastus medialis muscle
Saphenous nerve and saphenous branch of descending genicular artery
Infrapatellar branch of saphenous nerve
Lateral cutaneous nerve of thigh (cut)
Sartorius muscle (cut)
Iliopsoas muscle
Femoral nerve, artery and vein
Pectineus muscle
Deep artery of thigh
Adductor longus muscle
Adductor canal (opened by removal of sartorius muscle)
Saphenous nerve
Nerve to vastus medialis muscle
Adductor magnus muscle
Anteromedial intermuscular septum covers entrance of femoral vessels to popliteal fossa (adductor hiatus)
Sartorius muscle (cut)

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
		ANTERIOR			
Articularis genus	Distal anterior femoral shaft	Synovial capsule	Femoral	Pulls capsule superiorly in extension	May join with vastus intermedialis
Sartorius	ASIS	Prox. med. tibia (pes anserinus)	Femoral	Flex, ER hip	Can avulse from ASIS (avulsion fracture)
		Quadriceps			
Rectus femoris	1. AIIS 2. Sup. acetab. rim	Patella/tibial tubercle	Femoral	Flex thigh, extend leg	Can avulse from AIIS (avulsion fracture)
Vastus lateralis	Gtr. trochanter, lat. linea aspera	Lateral patella/ tibia tubercle	Femoral	Extend leg	Oblique fibers can affect Q angle
Vastus intermedius	Proximal femoral shaft	Patella/tibia tubercle	Femoral	Extend leg	Covers articularis genu
Vastus medialis	Intertrochant. line, med. linea aspera	Medial patella/ tibia tubercle	Femoral	Extend leg	Weak in many patellofemoral disorders

Deep dissection


Deep circumflex iliac artery
Lateral cutaneous nerve of thigh
Sartorius muscle (*cut*)
Iliopsoas muscle
Tensor fasciae latae muscle (*retracted*)
Gluteus medius and minimus muscles
Femoral nerve
Rectus femoris muscle (*cut*)
Ascending, transverse and descending branches of Lateral circumflex femoral artery
Medial circumflex femoral artery
Pectineus muscle (*cut*)
Deep artery of thigh
Perforating branches
Adductor longus muscle (*cut*)
Vastus lateralis muscle
Vastus intermedius muscle
Rectus femoris muscle (*cut*)
Saphenous nerve
Vastus medialis muscle
Quadriceps femoris tendon
Medial patellar retinaculum
Patellar ligament
External iliac artery and vein
Inguinal ligament (Poupart)
Femoral artery and vein (*cut*)
Pectineus muscle (*cut*)
Obturator canal
Obturator externus muscle
Adductor longus muscle (*cut*)
Anterior branch and Posterior branch of obturator nerve
Quadratus femoris muscle
Adductor brevis muscle
Adductor magnus muscle
Gracilis muscle
Cutaneous branch of obturator nerve
Femoral artery and vein (*cut*)
Articular branch
Saphenous branch
Adductor hiatus
Sartorius muscle (*cut*)
Adductor magnus tendon
Adductor tubercle on medial epicondyle of femur
Infrapatellar branch of Saphenous nerve
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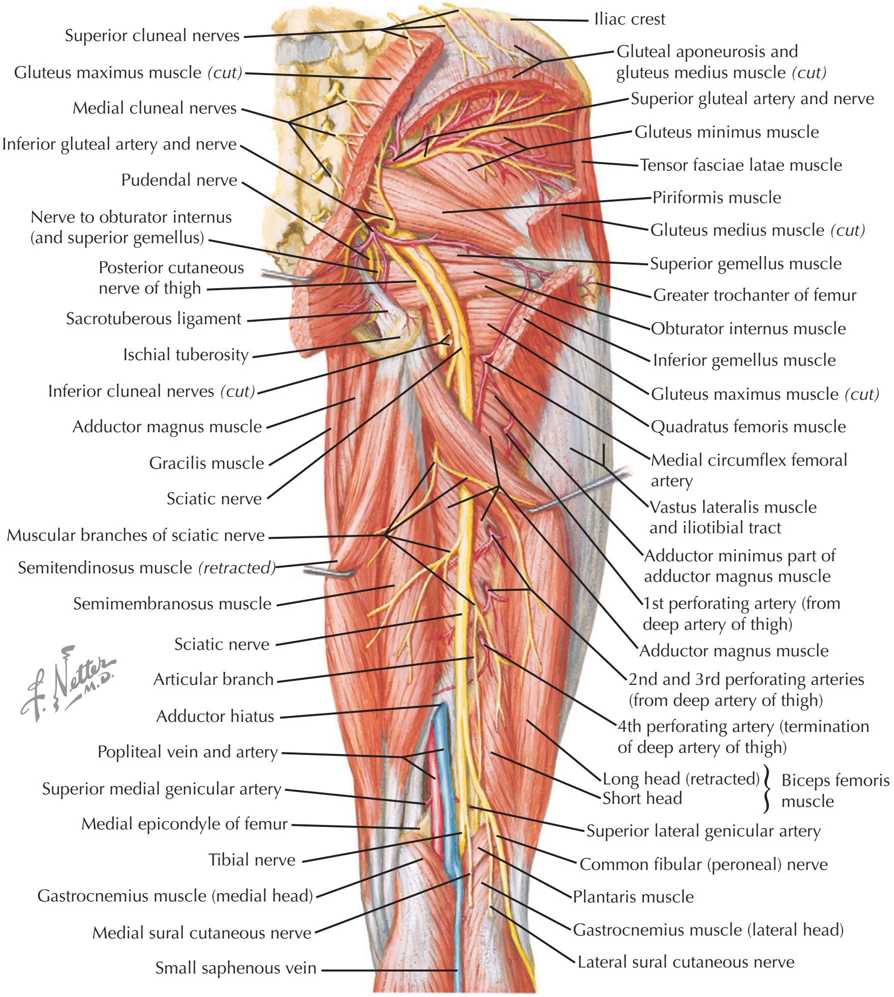
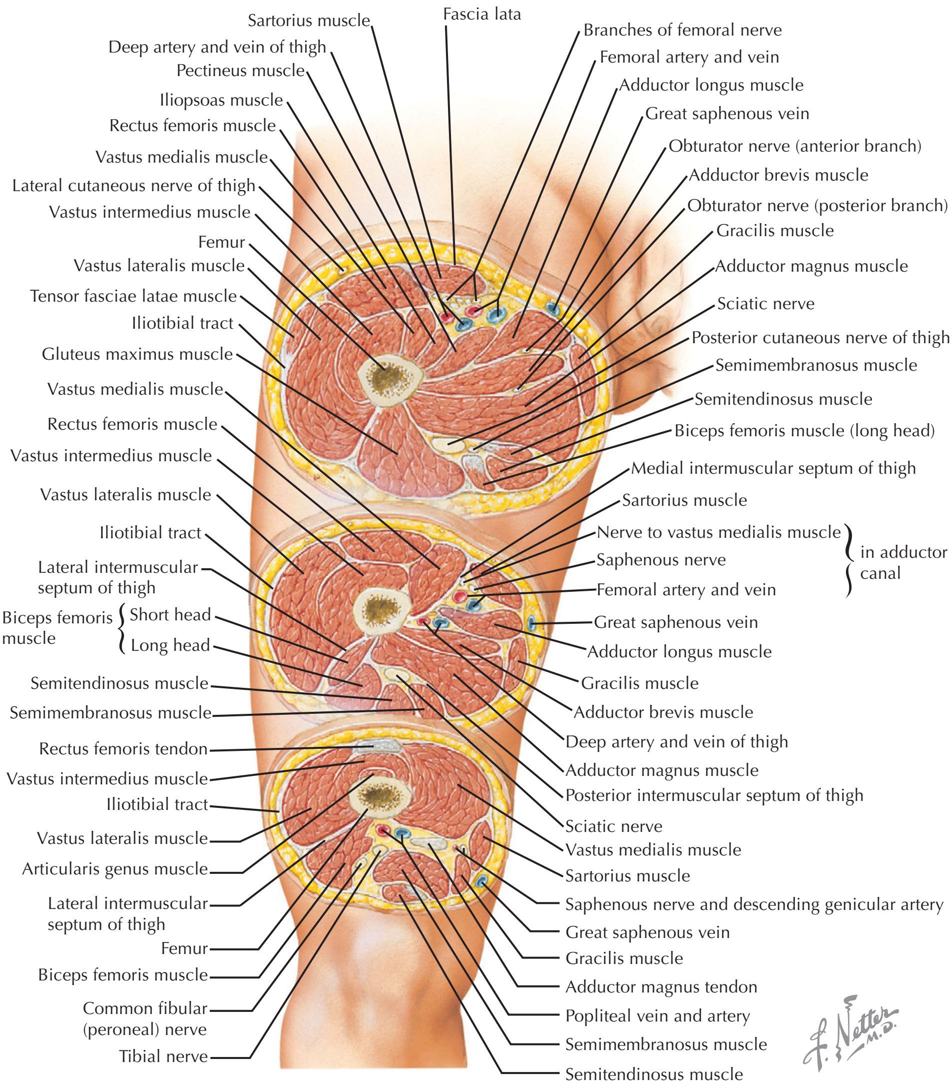
MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
MEDIAL					
Obturator externus	Ischiopubic rami, obturator memb	Piriformis fossa	Obturator	ER thigh	Insertion at start point of IM nail
Hip Adductors					
Adductor longus	Body of pubis (inferior)	Linea aspera (mid ⅓)	Obturator	Adducts thigh	Tendon can ossify
Adductor brevis	Body and inferior pubic ramus	Pectineal line, linea aspera	Obturator	Adducts thigh	Deep to pectineus
Adductor magnus	1. Pubic ramus 2. Ischial tub.	Linea aspera, add. tubercle	1. Obturator 2. Sciatic	Adducts & flex/extend thigh	Muscle has two separate parts
Gracilis	Body and inferior pubic ramus	Prox. med. tibia (pes anserinus)	Obturator	Adduct thigh, flex/IR leg	Used in ligament reconstruction
Hip Flexors					
Pectineus	Pectineal line of pubis	Pectineal line of femur	Femoral	Flex and adducts thigh	Part of femoral triangle floor

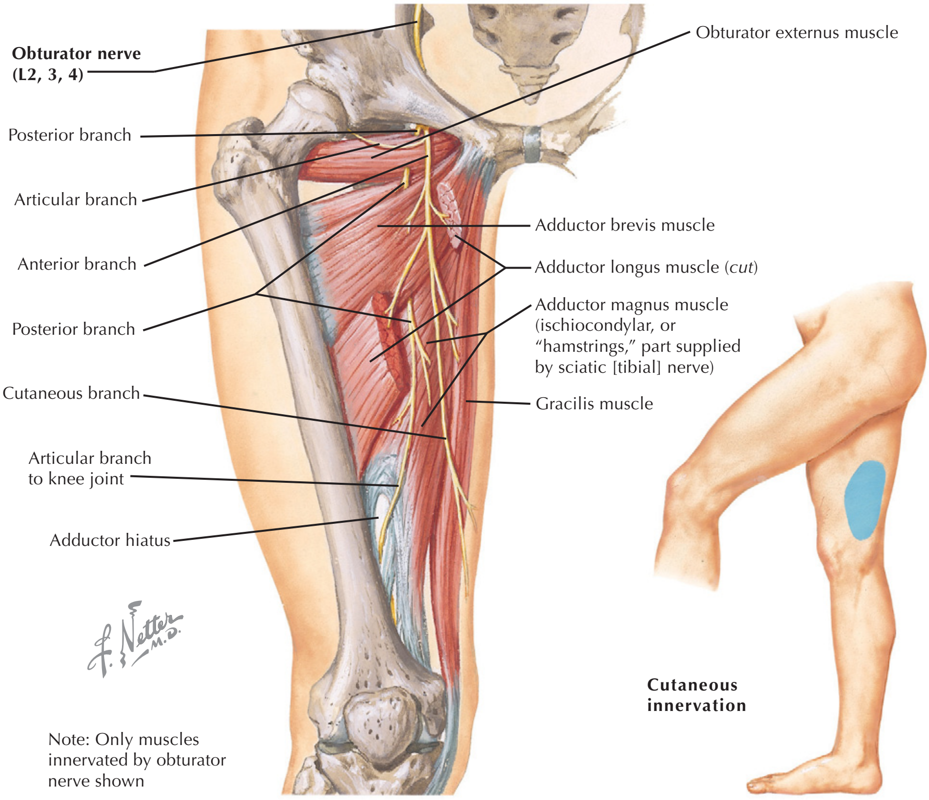
Deep dissection


Superior cluneal nerves
Gluteus maximus muscle *(cut)*
Medial cluneal nerves
Inferior gluteal artery and nerve
Pudendal nerve
Nerve to obturator internus (and superior gemellus)
Posterior cutaneous nerve of thigh
Sacrotuberous ligament
Ischial tuberosity
Inferior cluneal nerves *(cut)*
Adductor magnus muscle
Gracilis muscle
Sciatic nerve
Muscular branches of sciatic nerve
Semitendinosus muscle *(retracted)*
Semimembranosus muscle
Sciatic nerve
Articular branch
Adductor hiatus
Popliteal vein and artery
Superior medial genicular artery
Medial epicondyle of femur
Tibial nerve
Gastrocnemius muscle (medial head)
Medial sural cutaneous nerve
Small saphenous vein
Iliac crest
Gluteal aponeurosis and gluteus medius muscle *(cut)*
Superior gluteal artery and nerve
Gluteus minimus muscle
Tensor fasciae latae muscle
Piriformis muscle
Gluteus medius muscle *(cut)*
Superior gemellus muscle
Greater trochanter of femur
Obturator internus muscle
Inferior gemellus muscle
Gluteus maximus muscle *(cut)*
Quadratus femoris muscle
Medial circumflex femoral artery
Vastus lateralis muscle and iliotibial tract
Adductor minimus part of adductor magnus muscle
1st perforating artery (from deep artery of thigh)
Adductor magnus muscle
2nd and 3rd perforating arteries (from deep artery of thigh)
4th perforating artery (termination of deep artery of thigh)
Long head (retracted)
Short head
Biceps femoris muscle
Superior lateral genicular artery
Common fibular (peroneal) nerve
Plantaris muscle
Gastrocnemius muscle (lateral head)
Lateral sural cutaneous nerve

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
POSTERIOR: HAMSTRINGS					
Semitendinosus	Ischial tuberosity	Proximal medial tibia (pes anserinus)	Sciatic (tibial)	Extend thigh, flex leg	Tendon used in ligament reconstructions (ACL)
Semimembranosus	Ischial tuberosity	Posterior medial tibial condyle	Sciatic (tibial)	Extend thigh, flex leg	A border in medial approach
Biceps femoris: long head	Ischial tuberosity	Head of fibula	Sciatic (tibial)	Extend thigh, flex leg	Can avulse front origin (avulsion fx)
Biceps femoris: short head	Linea aspera, supracondylar line	Fibula, lateral tibia	Sciatic (peroneal)	Extend thigh, flex leg	Shares tendon insertion with long head


Sartorius muscle
Fascia lata
Deep artery and vein of thigh
Pectineus muscle
Iliopsoas muscle
Rectus femoris muscle
Vastus medialis muscle
Lateral cutaneous nerve of thigh
Vastus intermedius muscle
Femur
Vastus lateralis muscle
Tensor fasciae latae muscle
Iliotibial tract
Gluteus maximus muscle
Vastus medialis muscle
Rectus femoris muscle
Vastus intermedius muscle
Vastus lateralis muscle
Iliotibial tract
Lateral intermuscular septum of thigh
Biceps femoris muscle
Short head
Long head
Semitendinosus muscle
Semimembranosus muscle
Rectus femoris tendon
Vastus intermedius muscle
Iliotibial tract
Vastus lateralis muscle
Articularis genus muscle
Lateral intermuscular septum of thigh
Femur
Biceps femoris muscle
Common fibular (peroneal) nerve
Tibial nerve
Branches of femoral nerve
Femoral artery and vein
Adductor longus muscle
Great saphenous vein
Obturator nerve (anterior branch)
Adductor brevis muscle
Obturator nerve (posterior branch)
Gracilis muscle
Adductor magnus muscle
Sciatic nerve
Posterior cutaneous nerve of thigh
Semimembranosus muscle
Semitendinosus muscle
Biceps femoris muscle (long head)
Medial intermuscular septum of thigh
Sartorius muscle
Nerve to vastus medialis muscle
Saphenous nerve
Femoral artery and vein
in adductor canal
Great saphenous vein
Adductor longus muscle
Gracilis muscle
Adductor brevis muscle
Deep artery and vein of thigh
Adductor magnus muscle
Posterior intermuscular septum of thigh
Sciatic nerve
Vastus medialis muscle
Sartorius muscle
Saphenous nerve and descending genicular artery
Great saphenous vein
Gracilis muscle
Adductor magnus tendon
Popliteal vein and artery
Semimembranosus muscle
Semitendinosus muscle

STRUCTURE	RELATIONSHIP
COMPARTMENTS	
Anterior	Quadriceps: vastus lateralis, vastus intermedius, vastus medius, rectus femoris
Posterior	Biceps femoris (long head and short head), semitendinosus, semimembranosus, sciatic nerve
Medial	Adductor magnus, adductor longus, adductor brevis, gracilis, femoral artery and vein
FASCIOTOMIES	
Lateral incision	Release the anterior compartment and posterior compartment
Medial incision	Release the medial compartment


Obturator nerve (L2, 3, 4)
Posterior branch
Articular branch
Anterior branch
Posterior branch
Cutaneous branch
Articular branch to knee joint
Adductor hiatus
Obturator externus muscle
Adductor brevis muscle
Adductor longus muscle (*cut*)
Adductor magnus muscle (ischiocondylar, or "hamstrings," part supplied by sciatic [tibial] nerve)
Gracilis muscle
Cutaneous innervation

Note: Only muscles innervated by obturator nerve shown

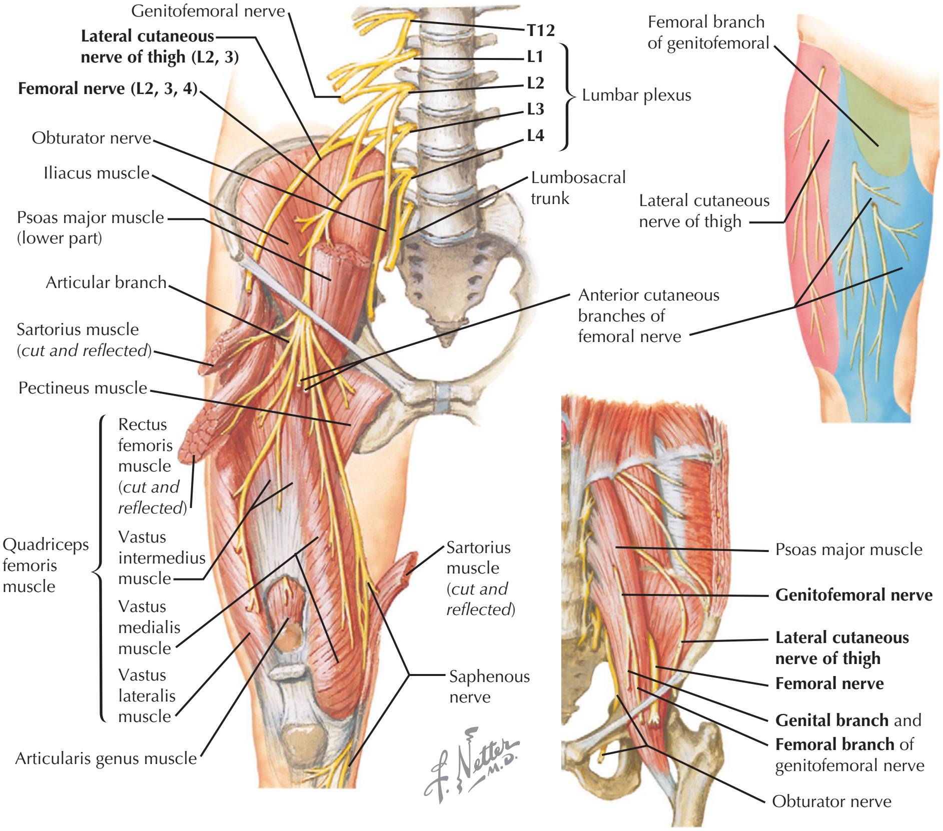
LUMBAR PLEXUS

Anterior Division

Obturator (L2-4): exits via obturator canal, splits into anterior and posterior divisions. Can be injured by retractors placed behind the transverse acetabular ligament.

Sensory: Inferomedial thigh: via **cutaneous branch of obturator nerve**

Motor: Gracilis (anterior division)
Adductor longus (anterior division)
Adductor brevis (anterior/posterior divisions)
Adductor magnus (posterior division)


Genitofemoral nerve
Lateral cutaneous nerve of thigh (L2, 3)
Femoral nerve (L2, 3, 4)
Obturator nerve
Iliacus muscle
Psoas major muscle (lower part)
Articular branch
Sartorius muscle (*cut and reflected*)
Pectineus muscle
Quadriceps femoris muscle
Rectus femoris muscle (*cut and reflected*)
Vastus intermedius muscle
Vastus medialis muscle
Vastus lateralis muscle
Articularis genus muscle
T12
L1
L2
L3
L4
Lumbar plexus
Lumbosacral trunk
Anterior cutaneous branches of femoral nerve
Sartorius muscle (*cut and reflected*)
Saphenous nerve
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Femoral branch of genitofemoral
Lateral cutaneous nerve of thigh
Psoas major muscle
Genitofemoral nerve
Lateral cutaneous nerve of thigh
Femoral nerve
Genital branch and
Femoral branch of genitofemoral nerve
Obturator nerve

LUMBAR PLEXUS

Genitofemoral (L1-2): pierces psoas, lies on anteromedial surface of psoas and divides into two branches

Sensory: Femoral branch: proximal anterior thigh (over femoral triangle)
Genital branch: scrotum/labia
Motor: None (in thigh)

Posterior Division

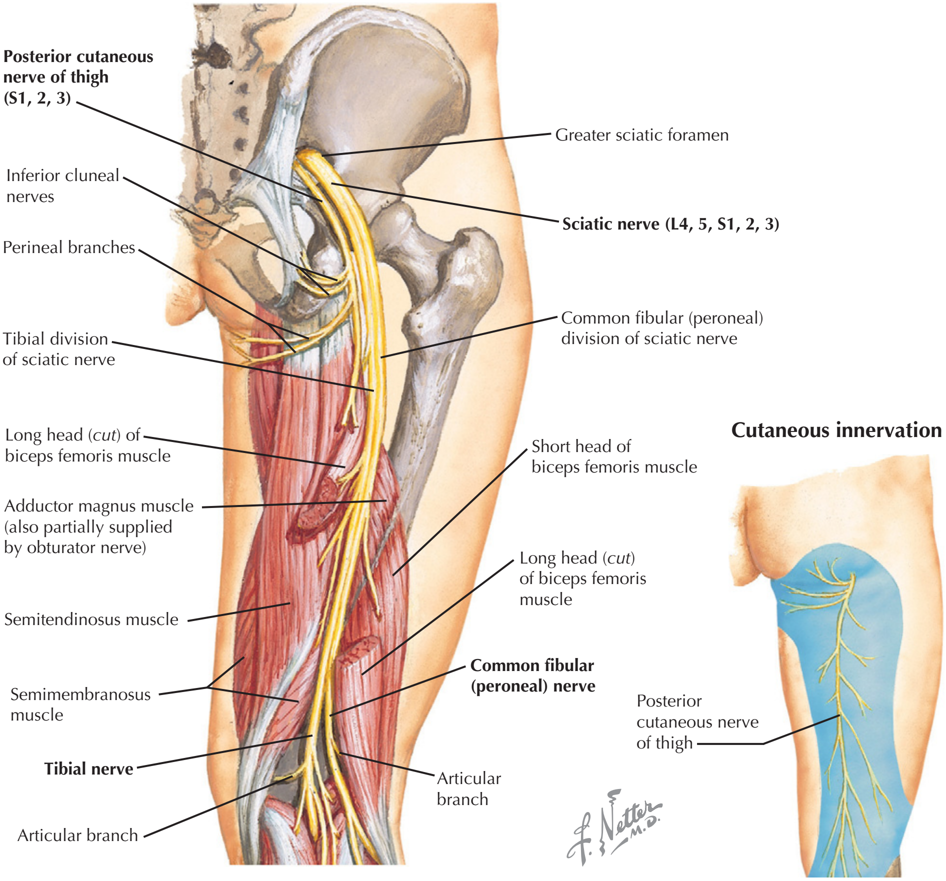
Lateral femoral cutaneous (LFCN) (L2-3): crosses inferior to ASIS (can be compressed at or near ASIS)

Sensory: Lateral thigh
Motor: None

Femoral (L2-4): lies b/w psoas major & iliacus; branches in femoral triangle. Saphenous nerve runs under sartorius.

Sensory: Anteromedial thigh—via **anterior/intermediate cutaneous nerves**
Motor: Psoas
Pectineus
Sartorius

- Quadriceps
    - Rectus femoris
    - Vastus lateralis
    - Vastus intermedialis
    - Vastus medialis


Posterior cutaneous nerve of thigh (S1, 2, 3)
Inferior cluneal nerves
Perineal branches
Tibial division of sciatic nerve
Long head (*cut*) of biceps femoris muscle
Adductor magnus muscle (also partially supplied by obturator nerve)
Semitendinosus muscle
Semimembranosus muscle
Tibial nerve
Articular branch
Greater sciatic foramen
Sciatic nerve (L4, 5, S1, 2, 3)
Common fibular (peroneal) division of sciatic nerve
Short head of biceps femoris muscle
Long head (*cut*) of biceps femoris muscle
Common fibular (peroneal) nerve
Articular branch
Cutaneous innervation
Posterior cutaneous nerve of thigh
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SACRAL PLEXUS

Sciatic nerve: a single nerve with 2 distinct parts; it divides in the distal thigh into tibial & common peroneal nerves

Anterior Division

Tibial (L4-S3): descends (as sciatic) in posterior thigh deep to hamstrings and superficial to adductor magnus muscle

Sensory: None (in thigh)
Motor: Biceps femoris (long head)
Semitendinosus
Semimembranosus

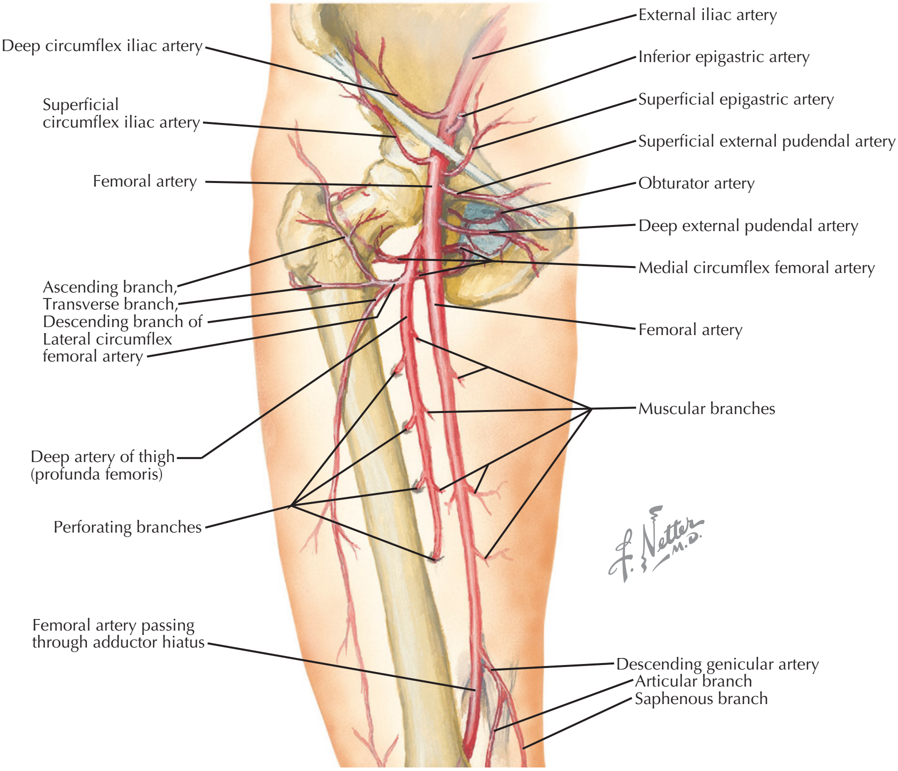
Posterior Division

Common peroneal (L4-S2): descends (as sciatic) in posterior thigh deep to hamstrings and superficial to adductor magnus

Sensory: None (in thigh)
Motor: Biceps femoris (short head)

Posterior femoral cutaneous nerve (PFCN) (S1-3): through greater sciatic foramen, medial to sciatic nerve

Sensory: Posterior thigh
Motor: None


External iliac artery
Deep circumflex iliac artery
Inferior epigastric artery
Superficial circumflex iliac artery
Superficial epigastric artery
Superficial external pudendal artery
Femoral artery
Obturator artery
Deep external pudendal artery
Medial circumflex femoral artery
Ascending branch,
Transverse branch,
Descending branch of
Lateral circumflex
femoral artery
Femoral artery
Muscular branches
Deep artery of thigh
(profunda femoris)
Perforating branches
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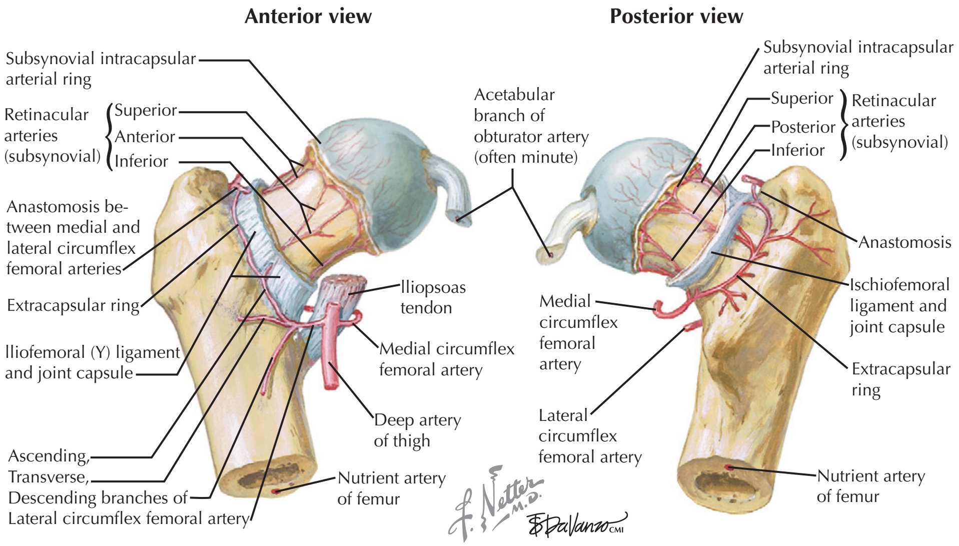
Femoral artery passing
through adductor hiatus
Descending genicular artery
Articular branch
Saphenous branch

ARTERY	BRANCHES	COMMENT
Obturator	Anterior/posterior branches	Runs through obturator foramen
FEMORAL ARTERY		
In femoral triangle, runs in adductor canal (under sartorius, b/w vastus medialis & adductor longus), then passes posterior through the adductor hiatus and becomes the popliteal artery posterior to the distal femur and knee.		
Femoral artery (superficial fem. [(SFA])	Superficial circumflex iliac Superficial epigastric Superficial and deep external pudendal Profunda femoris (deep artery) Descending genicular artery Articular branch Saphenous branch	Supplies superficial abdominal tissues Supplies superficial abdominal tissues Supplies subcutaneous tissues in pubic region and scrotum/labia majus Primary blood supply to thigh. See below Anastomosis at knee to supply knee
Profunda femoris (deep artery of thigh)	Medial femoral circumflex Lateral femoral circumflex Ascending branch Transverse branch Descending branch Perforators/muscular branch	Supplies femoral neck, under quad. femoris Supplies femoral neck Forms anastomosis at femoral neck To greater trochanter At risk in anteromedial approach to hip Supplies femoral shaft and thigh muscles


Anterior view
Posterior view
Subsynovial intracapsular arterial ring
Retinacular arteries (subsynovial)
Superior
Anterior
Inferior
Anastomosis between medial and lateral circumflex femoral arteries
Extracapsular ring
Iliofemoral (Y) ligament and joint capsule
Ascending,
Transverse,
Descending branches of
Lateral circumflex femoral artery
Nutrient artery of femur
Iliopsoas tendon
Medial circumflex femoral artery
Deep artery of thigh
Acetabular branch of obturator artery (often minute)
Medial circumflex femoral artery
Lateral circumflex femoral artery
Subsynovial intracapsular arterial ring
Superior
Posterior
Inferior
Retinacular arteries (subsynovial)
Anastomosis
Ischiofemoral ligament and joint capsule
Extracapsular ring
Nutrient artery of femur
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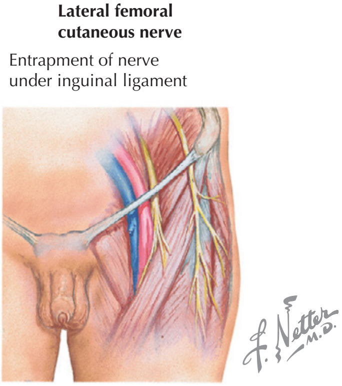
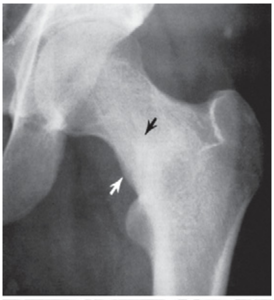
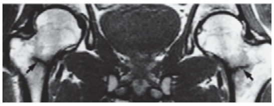
DaVanzo CMI

ARTERY	COURSE	COMMENT/SUPPLY
ARTERIES OF THE FEMORAL NECK		
Profunda Femoris		
Medial femoral circumflex (MFCA)	Between pectineus and psoas, then posterior to femoral neck under quadratus femoris	Main blood supply to adult femoral head Major contributor to extracapsular ring/anastomosis
Lateral femoral circumflex	Deep to sartorius & rectus fem.	Less significant blood supply in adult femoral head
Ascending branch	Ascends anterior femoral neck	Major contributor to extracapsular ring/anastomosis
Transverse branch	Across proximal femur to GT	Gives partial supply to greater trochanter (GT)
Descending branch	Under rectus femoris	At risk in anterolateral approach to hip
1st Perforator	Ascending branch	Can contribute to extracapsular ring/anastomosis
Extracapsular ring—formed at the base of the femoral neck primarily from branches of MFCA and LFCA		
Lateral branches	From ring, laterally toward GT	Supply greater trochanter
Ascending cervical arteries	Along extracapsular femoral neck	Branch from the extracapsular ring
Retinacular arteries	Along intracapsular femoral neck	Intracapsular continuation of cervical arteries Form a second intracapsular ring at base of head
Subsynovial intracapsular arterial ring—formed at the base of the femoral head		
Epiphyseal arteries Lateral epiphyseal art.	Enter bone at border of articular surface In posterosuperior neck	Will form intraosseous anastomoses Lat. epiphyseal supplies most of WB femoral head
Obturator Artery		
Artery of ligamentum teres	Thru ligamentum teres to fovea	Minimal supply to the adult femoral head
Medial epiphyseal art.	Interosseous terminal branches	Anastomose with lateral epiphyseal arteries
Other Arteries		
Superior & inferior gluteal		Can contribute to extracapsular ring/anastomosis
Pediatric femoral head blood supply: 0-4yr MFCA, LFCA, and ligamentum teres artery; 4-8yr: mostly MFCA, minimal LFCA and ligamentum teres artery; >8yrs: MFCA is predominant		


Lateral femoral cutaneous nerve
Entrapment of nerve under inguinal ligament
F. Netter M.D.

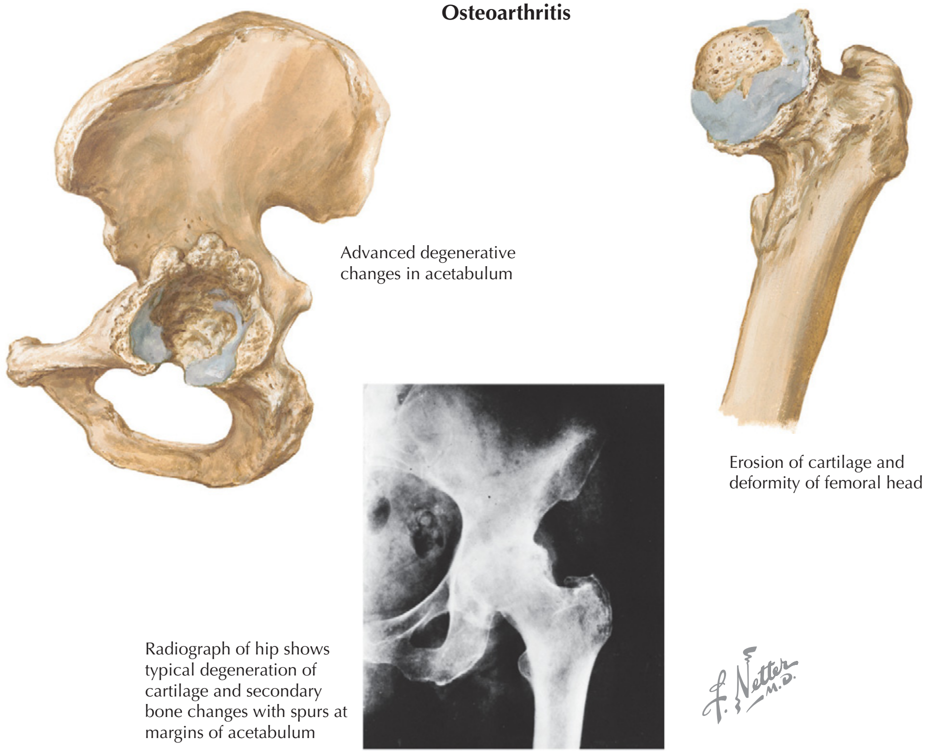

Arrows show the presence of buttressing and sclerosis in the femoral neck


Coronal MRI reveals bilateral fatigue fractures (arrows) in the femoral neck

Reprinted with permission from Resnick D. Kransdorf M. Bone and Joint Imaging, 3rd edition, Elesevier, Philadelphia, 2005.

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
FEMOROACETABULAR IMPINGEMENT			
• Subtle abnormal hip morphology causes bony abutment. 2 types ◦ *Cam:* femoral non-sphericity ◦ *Pincer:* acetabulum overcoverage • Causes early DJD	**Hx:** Insidious onset, groin pain, worse with activity **PE:** Decreased ROM (esp. IR), + impingement test (flex, add, IR hip)	**XR:** AP/lateral of hip *Cam:* femoral neck "bump," +/− herniation pit, decreased offset *Pincer:* increased acetabular coverage **MR:** Labral tear, chondral injury	1. NSAIDs, activity modification 2. Surgical dislocation and neck and/or acetabular reshaping 3. Osteotomy in selected cases 4. THA if advanced DJD
FEMORAL NECK STRESS (FATIGUE) FRACTURE			
• Excessive loading of hip • 2 types: tension (superior neck), compression (inferior neck) • Common in military recruits	**Hx:** Increased activity with new onset of hip/groin pain **PE:** +/− pain with and/or diminished ROM	**XR:** AP, AP in IR, lateral **MR:** Best study for early detection of fracture **BS:** Shows fx subacutely	• Compression: limited weight-bearing • Tension: urgent percutaneous pinning (prevent displacement)
MERALGIA PARESTHETICA			
• Nerve trapped near ASIS • Due to activity (hip extension), clothing (e.g., belt), or repetitive compression	**Hx:** Pain/burning in lateral thigh **PE:** Decr. sensation on lateral thigh, + meralgia	**XR:** AP/lateral of hip: rule out other pathology	1. Remove compressive entity (e.g., belt, tight clothing, etc.) 2. Surgical release: rare
SNAPPING HIP (COXA SALTANS)			
Snapping in hip. 3 types 1. External: ITB over GT 2. Internal: psoas over femoral head or iliopectineal eminence 3. Intraarticular: usually loose body	**Hx:** Snapping at hip +/− pain **PE:** Palpate the tendon (ITB or psoas tendon) then flex & extend hip, feeling for snap. (external over GT; internal over LT)	**XR:** AP/lateral hip: rule out osseous abnormality (e.g., spur) and hip DJD **MR:** Loose body, labral tear **US/bursography:** Psoas tendon	External/Internal: 1. Activity modification, PT 2. Consider injection 3. Surgical release: very rare Intraarticular: LB removal
TROCHANTERIC BURSITIS			
• Inflammation of bursa over greater trochanter • F>M, middle age	**Hx:** Lateral hip pain, cannot sleep on affected side **PE:** Point tender at trochanter, pain w/adduction	**XR:** AP pelvis, AP/lateral of hip: rule out spur, OA, calcified tendons	1. NSAIDs, PT (ITB stretching) 2. Steroid injection 3. Surgical excision—rare

Osteoarthritis

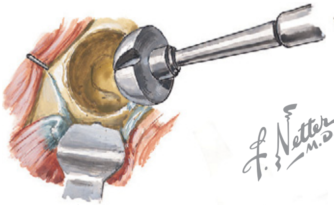


Advanced degenerative changes in acetabulum

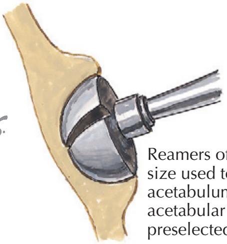
Erosion of cartilage and deformity of femoral head

Radiograph of hip shows typical degeneration of cartilage and secondary bone changes with spurs at margins of acetabulum

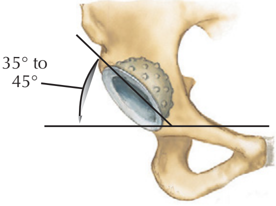
DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
OSTEOARTHRITIS			
• Loss or damage to articular cartilage • Etiology: Primary—idiopathic; Secondary—posttraumatic, infection, pediatric hip disease	**Hx:** Chronic hip or groin pain, increasing over time & with activity **PE:** Decreased ROM (first IR), + log roll, +/− flex contracture/antalgic gait	**XR:** AP pelvic/AP/lateral hip 1. Joint space narrowing 2. Osteophytes 3. Subchondral sclerosis 4. Bony cysts	1. NSAIDs/PT 2. Injection/activity modification, cane (in opposite hand) 3. Osteotomy (young) 4. Arthrodesis (young) 5. Total hip arthroplasty
OSTEONECROSIS (AVASCULAR NECROSIS/AVN)			
• Necrosis of femoral head due to vascular disruption • Assoc. w/trauma, steroid or EtOH use, inflammatory disorders. • M>F, 30-40's, 50% bilateral • Greater femoral head involvement, associated w/poor prognosis	**Hx:** Groin pain worse with activity **PE:** Limited ROM (esp IR & abd), antalgic gait **XR:** AP/lateral: stage-specific findings (see classification) **MRI:** Most sensitive study, shows early changes in femoral head **BS:** Replaced by MRI	**Classification:** Modified Ficat 0: Asymptomatic, nl XR, + MR 1: Symptomatic, nl XR, + MR 2: **XR:** sclerosis, no collapse 3: **XR:** + collapse (crescent sign) 4: Flat femoral head, nl acetabulum 5: Joint narrowing, early DJD 6: Advanced DJD incl. acetabulum	Stage: 0-1: Limited WB, observation 2: Core decompression 3: Consider vascularized fibula or femoral osteotomy 4-6: Total hip arthroplasty—appropriate for most patients. Hip fusion: in young laborers



Reamer of appropriate size inserted and acetabulum reamed to receive acetabular component



Reamers of increasing size used to enlarge acetabulum to fit acetabular cup of preselected size



Final position of cup 35° to 45° lateral inclination and 15° anteversion

TOTAL HIP ARTHROPLASTY

General Information

- Goals: alleviate pain, maintain personal independence, allow performance of activities of daily living (ADLs).
- Common procedure with high satisfaction rates for primary procedure; revisions are also becoming more common.
- Advances in techniques and materials are improving implant survival; this procedure available to younger pts.

Materials

- **Cups** (acetabulum) **and stems** (femur). Usually made of titanium. Stainless steel or cobalt chrome stems may be too stiff (i.e., modulus mismatch) and cause stress shielding.
- **Bearing surfaces:** Acetabular liners and femoral head implants. Polyethylene (PE) liner and cobalt-chrome (Co-Cr) femoral head currently most common. Ceramic and metal also used.
  - UHMWPE (ultra high molecular weight PE): good surface, but high wear rates and debris lead to aseptic loosening. Direct compression molding is preferred manufacturing technique. Sterilization with irradiation in nonoxygen environment promotes cross-linking. Highly cross-linked PE has much better wear rates.
  - Co-Cr: "supermetal" alloy. Commonly used for femoral bearing surface with PE liner. Metal on metal implants available. Debris particles are much smaller, create less histocytic response. Carcinogenesis is a theoretic concern.
  - Ceramic (alumina): Excellent wear rates, but brittle (could fracture). Can be used with PE liner or ceramic cup.

Techniques

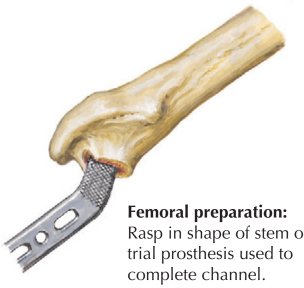
- **Two types of fixation:** 1. Cement, 2. Uncemented/biologic
  - **Cement:** Methylmethacrylate. Most often used in elderly patients. Provides immediate static fixation, no remodeling potential. Cement resists compression better than tension. As such, femoral implants do better than acetabular cups with this fixation. 3rd generation cementing techniques: pressurization, precoat stem, centralizer/restrictor, canal preparation, 2mm mantle
  - **Uncemented/biologic:** Used in younger patients (increasing popularity). Bone ongrowth or ingrowth—bone grows onto/into implant. Has remodeling potential, gives dynamic fixation. Not good a good choice in post-irradiated hip.
- Fixation is NOT immediate, needs initial fixation for stability: 2 techniques.
  - Press fit: Implant 1-2mm larger than bone. Bone hoop stresses provide initial fixation while bone on/ingrows.
  - Line to line: Implant and bone are same size. Screws used to provide initial fixation while bone on/ingrows.
- Optimal porous ongrowth pore size: 50-150 micrometers. Ongrowth surface area varies.
- Current gold standard implant: Uncemented (ingrowth) acetabular cup and cemented femoral steel. Trends are changing, and more uncemented femoral components and alternative bearing surfaces are being used more frequently.
- Head size affects stability (larger is more stable) and wear (large head = high volumetric wear). 28mm is optimal size.

Indications

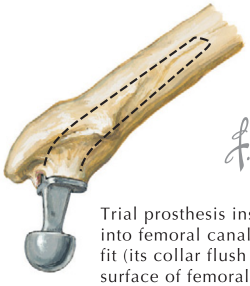
- **Arthritis of hip**
  - Common etiologies: osteoarthritis, rheumatoid arthritis, osteonecrosis, prior pediatric hip disease
  - Clinical symptoms: groin/hip pain, worse with activity, gradually worsening over time, decreased functional capacity
  - Radiographic findings: appropriate radiographic evidence of hip arthritis should be present

Osteoarthritis	**Rheumatoid arthritis**
1. Joint space narrowing	1. Joint space narrowing
2. Sclerosis	2. Periarticular osteoporosis
3. Subchondral cysts	3. Joint erosions
4. Osteophyte formation	4. Ankylosis

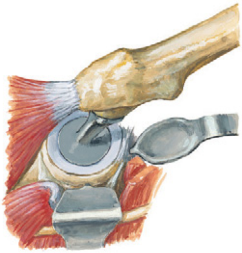
  - Failed conservative treatment: NSAIDs, activity modification, weight loss, PT, cane (contralateral hand), injections
  - Other: Fractures (e.g., femoral neck with hip DJD), tumors, developmental disorders (e.g., DDH, etc)



Femoral preparation: Rasp in shape of stem of trial prosthesis used to complete channel.



Trial prosthesis inserted into femoral canal to ensure fit (its collar flush with cut surface of femoral neck)



Reduction of hip with prosthesis in place.

TOTAL HIP ARTHROPLASTY—CONTINUED

Contraindications

- Absolute
  - Neuropathic joint
  - Infection
  - Medically unstable patient (e.g., severe cardiopulmonary disease). Patient may not survive the procedure.
- Relative
  - Young, active patients. These patients can wear out the prosthesis many times in their lives.

Alternatives

- Considerations: age, activity level, overall medical health
- Osteotomy: femoral or pelvic; usually performed in younger patients
- Arthrodesis/fusion: young laborers with isolated unilateral disease (i.e., normal spine, knee, ankle, contralateral hip)

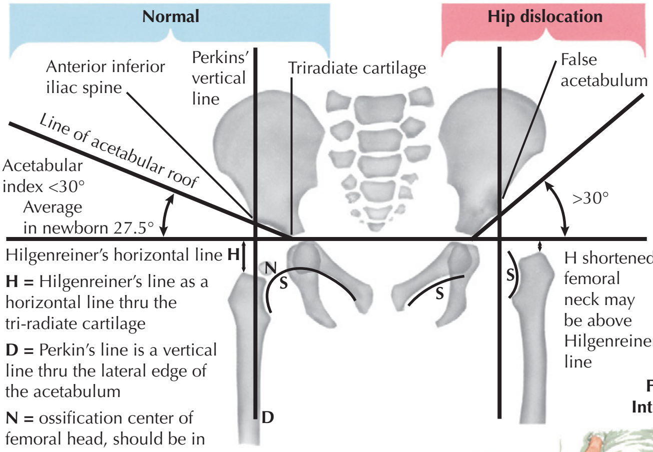
Procedure

- Approaches
  - Posterior, lateral, and anterolateral approaches
  - Minimally invasive, one- and two-incision approaches are becoming more common.
- Steps
  - Acetabulum: remove labrum & osteophytes, ream to a cortical rim, implant cup (35-45° coronal tilt, 15-30° anteversion)
  - Femur: dislocate head, cut neck, remove head, find and broach canal (lateralize as needed)—stem cannot be in varus, implant stem, trial head, & neck. Implant the appropriate head/neck and acetabular liner.

Complications

- Infection: Diagnose with labs and aspiration. Prevention is mainstay: perioperative antibiotics, meticulous prep/drape technique, etc. Acute/subacute: irrigation & debridement with PE exchange. Late: one- or two-stage revision.
- Loosening: Patient often complains of "start up" pain. Radiolucent lines seen on plain radiographs. Most often caused by osteolysis. Osteolysis caused from macrophage response to submicron-sized wear particles (usually PE).
- Dislocation: Can be caused from component (either femur or acetabulum) malalignment or soft tissue injury/dysfunction. Decreased in posterior approach when short external rotators are repaired during closure.
- Neurovascular injury
  - Sciatic nerve: peroneal division (resulting in foot drop) at risk from vigorous retraction in posterior approach
  - Femoral nerve: with vigorous retraction in anterolateral approach
  - Obturator vessels: under the transverse acetabular lig., injured with retractors or anteroinferior quadrant cup screw
  - External iliac vessels: at risk if cup screw placed in anterosuperior quadrant (posterosuperior quadrant is safe)
  - Medial femoral circumflex artery: under quadratus femoris, at risk in posterior approach if muscle is taken down
- Heterotopic ossification: Usually in predisposed patients. Can cause decreased ROM. One dose of XRT can prevent it.
- Medical complications: Deep venous thrombosis (DVT) & pulmonary embolus (PE) known risk of THA. Prophylaxis must be initiated.
- Periprosthetic fracture of femur
  - Stable implant: ORIF (plates, cables, +/− bone graft).
  - Unstable implant: replace with longer stem that passes fx site.

Development dysplasia of hip

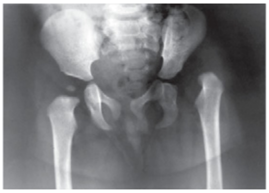

Normal
Hip dislocation
Anterior inferior iliac spine
Perkins' vertical line
Triradiate cartilage
False acetabulum
Line of acetabular roof
Acetabular index <30°
Average in newborn 27.5°
>30°
Hilgenreiner's horizontal line
H
N
S
S
S
D
H shortened; femoral neck may be above Hilgenreiner's line

H = Hilgenreiner's line as a horizontal line thru the tri-radiate cartilage

D = Perkin's line is a vertical line thru the lateral edge of the acetabulum

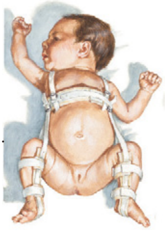
N = ossification center of femoral head, should be in inner lower quadrant.

S = Shenton's curved line (broken in hip dislocation)



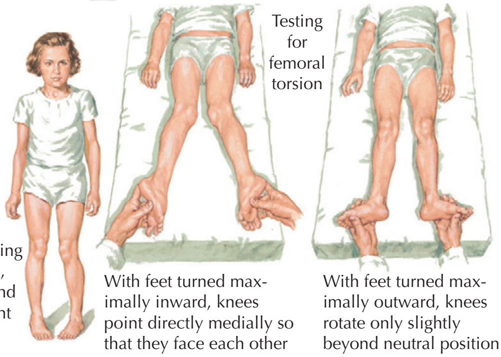
Radiograph of 15 month old with DDH showing classic signs: increased acetabular index, a broken Shenton's line and a false acetabulum.

Pavlik harness



Harness adjusted to allow comfortable abduction within safe zone. Forced abduction beyond this limit may lead to avascular necrosis of femoral head. Posterior strap serves as checkrein to prevent hip from *adducting* to point of redislocation.

Femoral Anteversion
Internal Femoral Torsion


Testing for femoral torsion

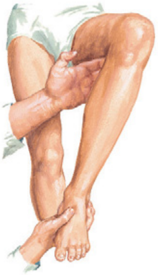
In standing position, knees and feet point inward

With feet turned maximally inward, knees point directly medially so that they face each other

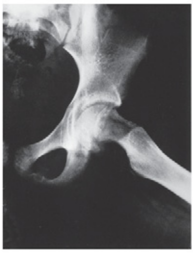
With feet turned maximally outward, knees rotate only slightly beyond neutral position

DESCRIPTION	EVALUATION	TREATMENT
DEVELOPMENTAL DYSPLASIA OF THE HIP (DDH)		
• Abnormal hip development resulting in dislocation, subluxation, or laxity of hip • Most from capsular laxity & positioning; irreducible teratologic form seen in congenital syndromes or neuromuscular diseases. • Risk factors: female, breech, first born, family hx, decreased uterine space conditions • Early diagnosis and treatment essential	**Hx:** Usually unnoticed by parents. +/− risk factors **PE:** Barlow (dislocation), + Ortolani (relocation), +/− Galeazzi test & decreased abduction **XR:** Useful after 6mo (femoral head begins to ossify). Look for position in acetabulum. Multiple radiographic lines help evaluate hip. **US:** Useful in neonate. Alpha angle >60 is nl.	**Obtain & maintain concentric reduction:** ◦ 0-6mo: Pavlik harness ◦ 6-24mo: Closed reduction, spica cast; open reduction if CR fails ◦ 2-4yr: Open reduction with or without femoral osteotomy ◦ >4yr: Acetabular osteotomy; teratologic hips need open treatment
COMPLICATIONS: Osteonecrosis of femoral head: can occur during reduction or from nonanatomic positioning postreduction.		
FEMORAL ANTEVERSION		
• Internal rotation of femur, femoral anteversion does not decrease properly • #1 cause of intoeing	**Hx:** Usually presents 3-6yr **PE:** Femur IR (IR>65°), patella points medial, intoeing gait	1. Most spontaneously resolve 2. Derotational osteotomy if it persists past age 10 (mostly cosmetic)

Slipped Capital Femoral Epiphysis

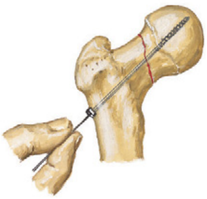


Best diagnostic sign is physical examination. With patient supine, as thigh is flexed it rolls into external rotation and abduction



Frog-leg radiograph, which demonstrates slipped epiphysis more clearly, always indicated when disorder is suspected

Slipped Capital Femoral Epiphysis: Operative Fixation



Threaded cannulated screw introduced over guide wire

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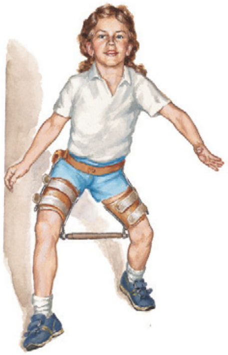
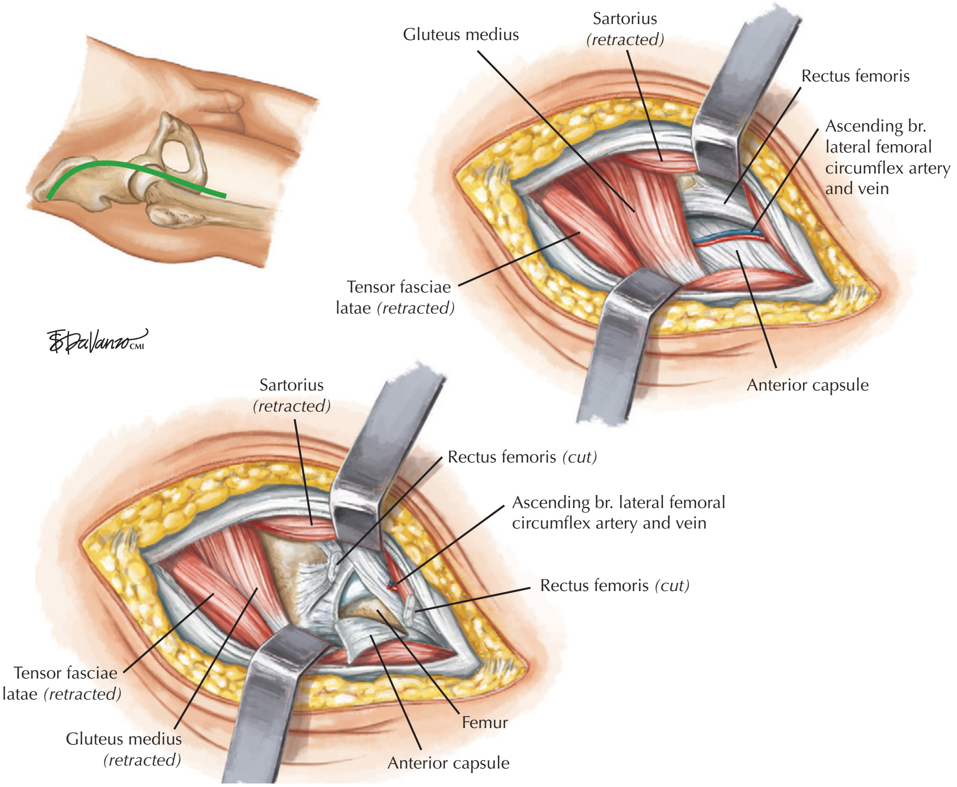
Legg-Calve-Perthes Disease



Young girl walking in Atlanta Scottish Rite Children's Hospital brace. Advantages of brace: allows child to walk without support, allows for further abduction by telescoping bar, and permits free knee and ankle motion

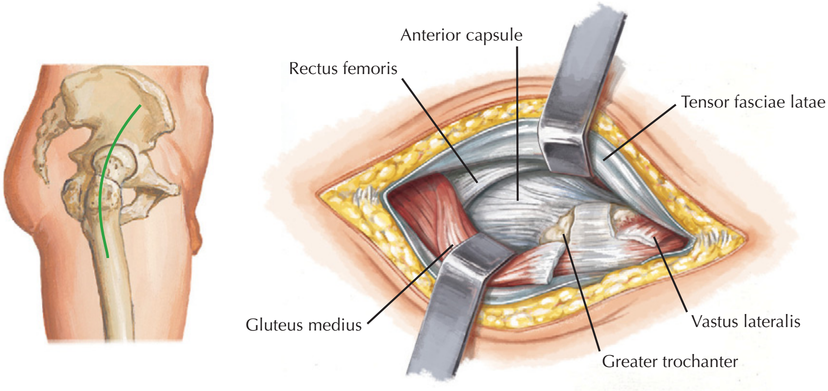
DESCRIPTION	EVALUATION	TREATMENT
LEGG-CALVE-PERTHES DISEASE		
• Idiopathic osteonecrosis of femoral head • Femoral head must revascularize, can take 2-5yr to complete • Prognosis good with onset <6yo & minimal lat. pillar involvement • Catterall & Herring classifications • Poor healing results in hip OA as adult	**Hx:** Boys (4:1), usually 4-8y.o. Limp with hip, thigh, or knee pain. No trauma. **PE:** Decr. ROM (esp. IR & abduction) **XR:** AP/lateral hip: sclerosis in early stages. "Crescent sign" sign of subchondral collapse/fx **MR:** Will show early necrosis when plain x-rays are still normal.	• Goals: 1. Relieve pain symptoms; 2. Maintain/obtain full ROM; 3. Contain femoral head • Traction, reduced weight-bearing • ROM: rest, traction, +/– therapy • Osteotomy: femoral or acetabular usually reserved for older patients
SLIPPED CAPITAL FEMORAL EPIPHYSIS (SCFE)		
• Displacement ("slip") of femoral epiphysis through the proximal physis • Classification: Stable: able to bear weight (WB); Unstable: unable to WB • Associated with obesity, renal & thyroid disease • Epiphysis is usually posterior to neck but remains in acetabulum.	**Hx:** 10-16y.o., obese, limp, hip or knee pain, +/– weight bear (WB) **PE:** Decr. ROM (esp. IR), hip ER with flexion, antalgic gait (if able to WB) **XR:** AP/lateral: BOTH hips, will show slip; Klein's line should intersect epiphysis. Graded on percent of epiphysis that slipped: Gr 1:<33%, Gr 2: 33-50%, Gr 3: >50%	• Percutaneous in situ screw fixation • One cannulated screw is gold standard • Progressive slip may still occur • Forceful reduction NOT recommended • Prophylactic pinning of contralateral side is common and supported
COMPLICATIONS: Osteonecrosis (50% in unstable slips), chondrolysis, early osteoarthritis		
TRANSIENT SYNOVITIS		
• Aseptic hip effusion of unknown cause • May be caused by post viral syndrome or overuse • Common cause of hip pain & limp • Diagnosis of exclusion, r/o septic hip	**Hx:** Ages 2-5y.o., M>F, insidious onset limp **PE:** Decreased ROM (esp. abd), antalgic gait **XR:** r/o other hip pathology **LABS:** CBC, ESR, blood culture **US:** Evaluate for effusion (if suspect septic hip)	• Aspirate hip under anesthesia with fluoroscopy if PE & labs indicate infection • Septic hip requires I&D and antibiotics • Transient synovitis resolves: 2-10 days • Observation, rest, +/– NSAIDs

Anterior Approach to Hip

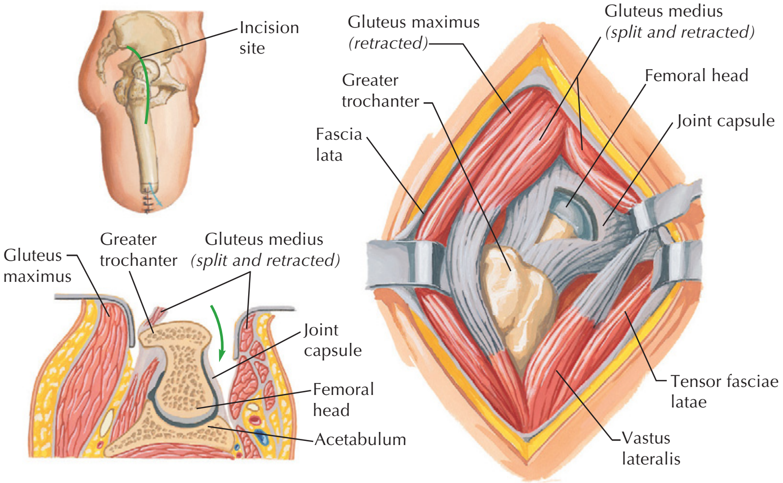

Gluteus medius
Sartorius (retracted)
Rectus femoris
Ascending br. lateral femoral circumflex artery and vein
Tensor fasciae latae (retracted)
Anterior capsule
DaVanzo CMI
Sartorius (retracted)
Rectus femoris (cut)
Ascending br. lateral femoral circumflex artery and vein
Rectus femoris (cut)
Tensor fasciae latae (retracted)
Gluteus medius (retracted)
Femur
Anterior capsule

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
ANTERIOR (SMITH-PETERSON) APPROACH TO HIP			
Open reduction ∘ Pediatric congenital hip dislocation ∘ Adult anterior dislocations Irrigation & debridement Fractures: anterior femoral head (ORIF) Hemiarthroplasty Tumor excision	*Superficial* • Sartorius (femoral nerve) • Tensor fasciae latae (SGN) *Deep* • Rectus femoris (femoral n.) • Gluteus medius (SGN)	• Lateral femoral cutaneous n. • Femoral nerve • Ascending branch of lateral femoral circumflex artery	• Retract LFCN anteriorly • Ascending branch of LFCA must be ligated in approach • Take down both heads of rectus femoris to expose joint • Vigorous medial retraction can injure femoral nerve
MEDIAL (LUDLOFF) APPROACH TO HIP			
Pediatric hip dislocation Adductor or psoas release Irrigation & debridement	*Superficial:* Intermuscular plane • Adductor longus (obturator n.) • Gracilis (obturator n.) *Deep* • Adductor brevis (obturator n.) • Adductor magnus (obturator & sciatic n.)	• Obturator nerve (ant. division) • Medial femoral circumflex artery • Obturator nerve (post. division) • External pudendal artery (proximally)	• Used most in pediatric cases • Good access to transverse acetabular ligament & psoas tendon, which can block closed hip reduction. Poor access to acetabulum.

Anterolateral (Watson-Jones) Approach to Hip Joint

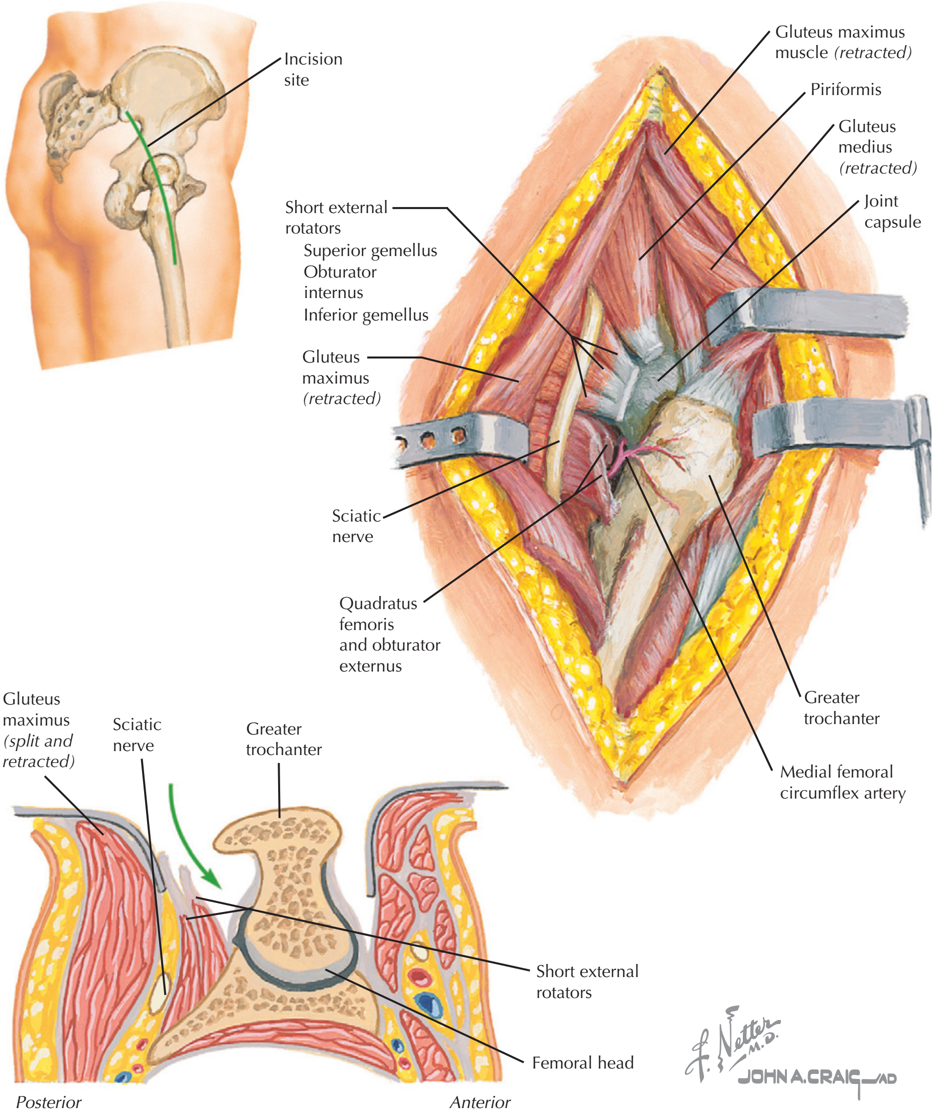

Anterior capsule
Rectus femoris
Tensor fasciae latae
Gluteus medius
Vastus lateralis
Greater trochanter

Lateral (Transtrochanteric) Approach to Hip Joint


Incision site
Gluteus maximus (retracted)
Gluteus medius (split and retracted)
Femoral head
Greater trochanter
Joint capsule
Fascia lata
Gluteus maximus
Greater trochanter
Gluteus medius (split and retracted)
Joint capsule
Femoral head
Acetabulum
Tensor fasciae latae
Vastus lateralis

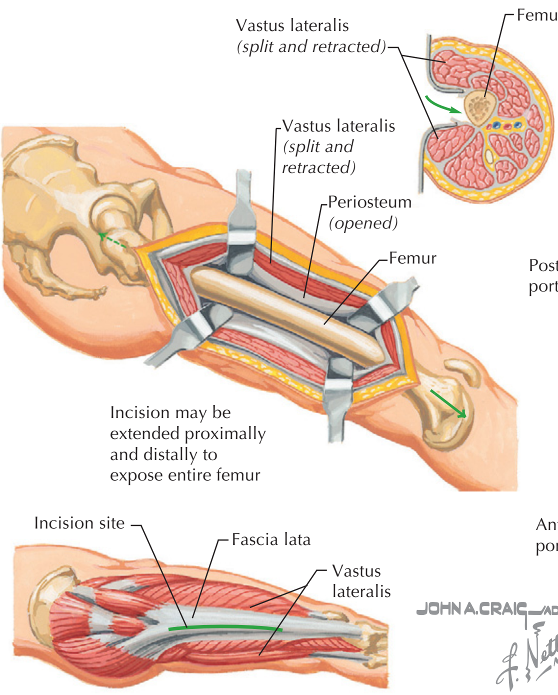
USES	INTERNERVOUS PLANE	DANGERS	COMMENT
ANTEROLATERAL (WATSON-JONES) APPROACH TO HIP			
• Total hip arthroplasty • Hemiarthroplasty • ORIF of proximal femur fxs	Intermuscular plane • Tensor fasciae latae (SGN) • Gluteus medius (SGN)	• Descending branch of LFCA (under rectus femoris) • Femoral nerve	• Must detach abductors (either osteotomy or extensive release) • Vigorous medial retraction can injure femoral nerve
LATERAL (HARDINGE) APPROACH TO HIP			
• Total hip arthroplasty (not used for revisions)	• Split gluteus medius (superior gluteal n.) • Split vastus lateral n. distally (femoral n.)	• Superior gluteal artery • Femoral nerve • Femoral artery & vein • Superior gluteal nerve	• No osteotomy of greater trochanter required; less dislocation risk • Split gluteus medius ⅓ anterior, ⅔ posterior; release minimus

Posterior (Southern) Approach to Hip Joint


Incision site
Gluteus maximus muscle (retracted)
Piriformis
Gluteus medius (retracted)
Joint capsule
Short external rotators
Superior gemellus
Obturator internus
Inferior gemellus
Gluteus maximus (retracted)
Sciatic nerve
Quadratus femoris and obturator externus
Greater trochanter
Medial femoral circumflex artery
Gluteus maximus (split and retracted)
Sciatic nerve
Greater trochanter
Short external rotators
Femoral head
Posterior
Anterior
F. Netter M.D.
JOHN A.CRAIG AD

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
POSTERIOR (MOORE/SOUTHERN) APPROACH TO HIP			
• Total hip arthroplasty • Hemiarthroplasty • Fractures/ORIF • Posterior hip dislocation	Split gluteus maximus (inferior gluteal n.)	• Sciatic nerve • Inferior gluteal artery • Medial femoral circumflex artery (under quadratus femoris)	• Reflecting piriformis protects sciatic nerve • IGA injured in proximal extension • Repair short ERs to prevent dislocation

Lateral Approach to Thigh (Femur)


Vastus lateralis (split and retracted)
Femur
Vastus lateralis (split and retracted)
Periosteum (opened)
Femur
Incision may be extended proximally and distally to expose entire femur
Incision site
Fascia lata
Vastus lateralis
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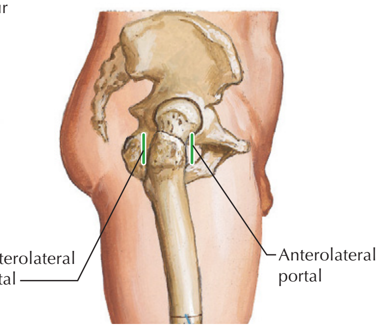
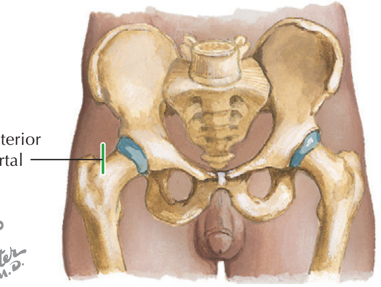
Hip Arthroscopy Portals


Posterolateral portal
Anterolateral portal


Anterior portal

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
THIGH FASCIOTOMIES			
See page 269.			
LATERAL APPROACH TO THIGH			
• Fractures • Tumors	Split vastus lateralis (femoral nerve) or elevate it off intermuscular septum	• Descending branch of lateral femoral circumflex artery • Perforates from profunda femoris • Superior lateral geniculate a.	• Incision can be large or small; made along line between greater trochanter and lateral condyle • Arteries (at left) encountered or require ligation
HIP ARTHROSCOPY PORTALS			
• Arthroscopy used for diagnosis, labral tears, loose body removal, synovectomy, irrigation, and debridement			
Anterior	Intersection of vertical line from ASIS and horizontal line from tip of GT	1. Lateral femoral cutaneous n. 2. Femoral nerve 3. Ascending branch of LFCA	Second portal. Angle 45° cephalad, 30° to midline. Pierce sartorius & rectus before capsule
Anterolateral	Anterior tip of greater trochanter (GT)	1. Superior gluteal nerve	Safest portal, establish 1st. Pierce gluteus medius & lateral capsule
Posterolateral	Posterior tip of greater trochanter (GT)	1. Sciatic nerve	Last portal. Pierce gluteus medius/minimus
• Long cannulae, arthroscope, instruments, and traction are needed for hip arthroscopy.			

CHAPTER 9

Leg/Knee

Topographic Anatomy 286

Osteology 287

Radiology 290

Trauma 292

Joints 296

Minor Procedures 306

History 307

Physical Exam 308

Origins and Insertions 314

Muscles 315

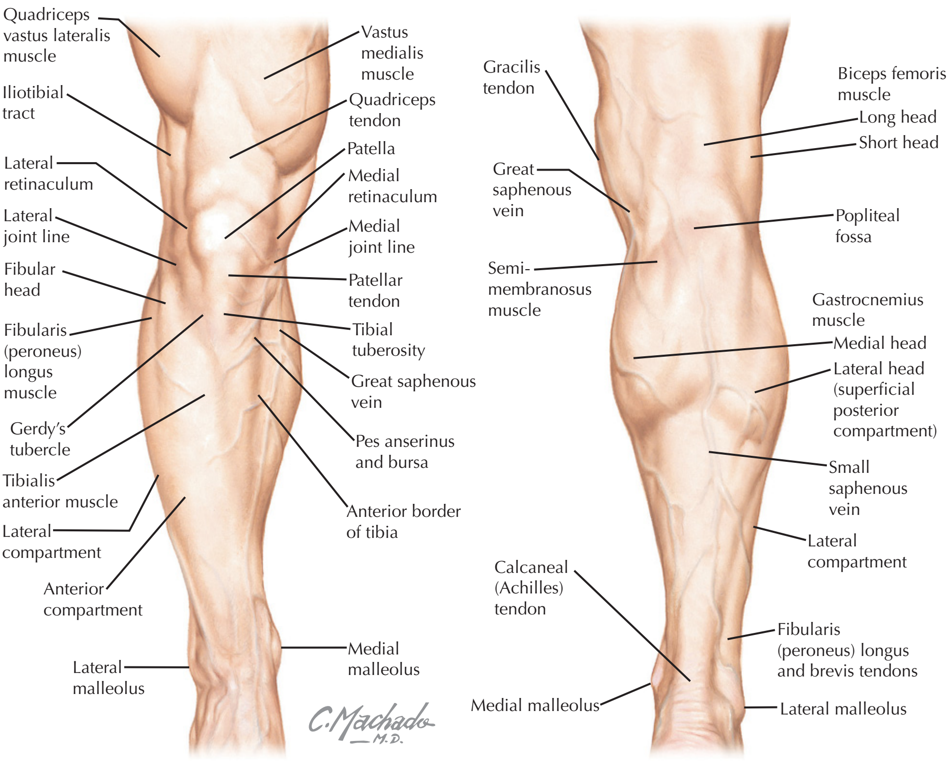
Nerves 320

Arteries 322

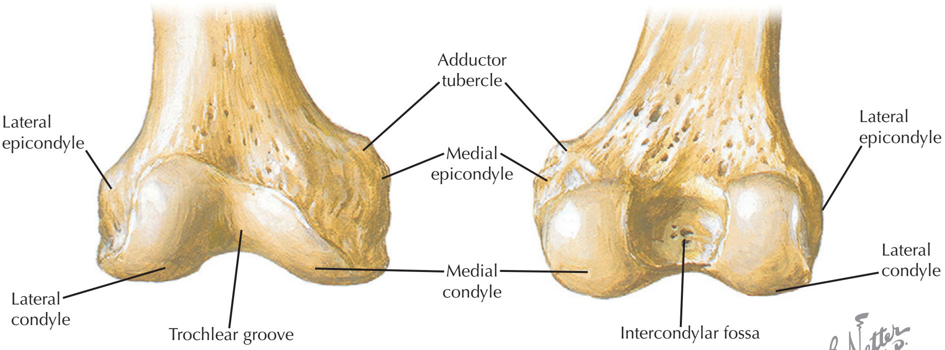
Disorders 323

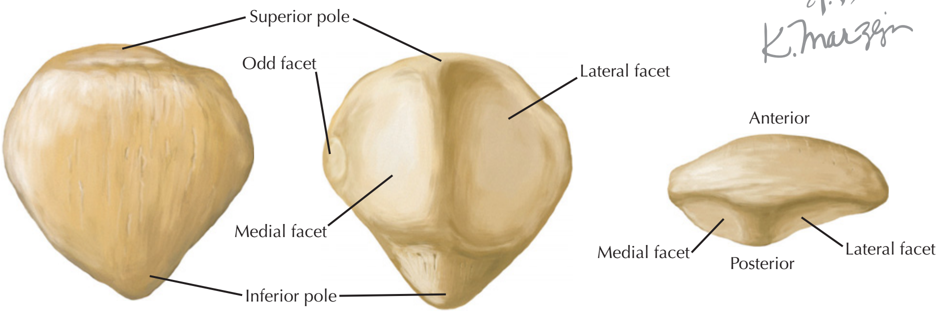
Pediatric Disorders 332

Surgical Approaches 335


Quadriceps vastus lateralis muscle
Iliotibial tract
Lateral retinaculum
Lateral joint line
Fibular head
Fibularis (peroneus) longus muscle
Gerdy's tubercle
Tibialis anterior muscle
Lateral compartment
Anterior compartment
Lateral malleolus
Vastus medialis muscle
Quadriceps tendon
Patella
Medial retinaculum
Medial joint line
Patellar tendon
Tibial tuberosity
Great saphenous vein
Pes anserinus and bursa
Anterior border of tibia
Medial malleolus
C. Machado M.D.
Gracilis tendon
Great saphenous vein
Semi-membranosus muscle
Calcaneal (Achilles) tendon
Medial malleolus
Biceps femoris muscle
Long head
Short head
Popliteal fossa
Gastrocnemius muscle
Medial head
Lateral head (superficial posterior compartment)
Small saphenous vein
Lateral compartment
Fibularis (peroneus) longus and brevis tendons
Lateral malleolus

STRUCTURE	CLINICAL APPLICATION
Iliotibial tract (band)	Tightness can cause lateral knee and/or thigh pain.
Quadriceps muscle	Atrophy can indicate an injury and/or contribute to knee pain.
Quadriceps tendon	Can rupture with eccentric loading. Defect is palpated here.
Patella	Tenderness can indicate fracture; swelling can be prepatellar bursitis.
Patellar tendon	Can rupture with eccentric loading. Defect is palpated here.
Patellar retinaculum	Patellar femoral ligaments palpated here. They can be injured in patellar dislocation. Plicae can also be palpated here.
Joint line	Tenderness here can indicate meniscal pathology.
Tibial tubercle	Tender in Osgood-Schlatter disease.
Pes anserinus & bursa	Insertion of medial hamstrings. Bursitis can develop. Site of hamstring tendon harvest.
Gerdy's tubercle	Insertion of the iliotibial tract (band).
Popliteal fossa	Popliteal artery pulse can be palpated here.
Muscle compartments	Will be firm or tense in compartment syndrome. Anterior most common.

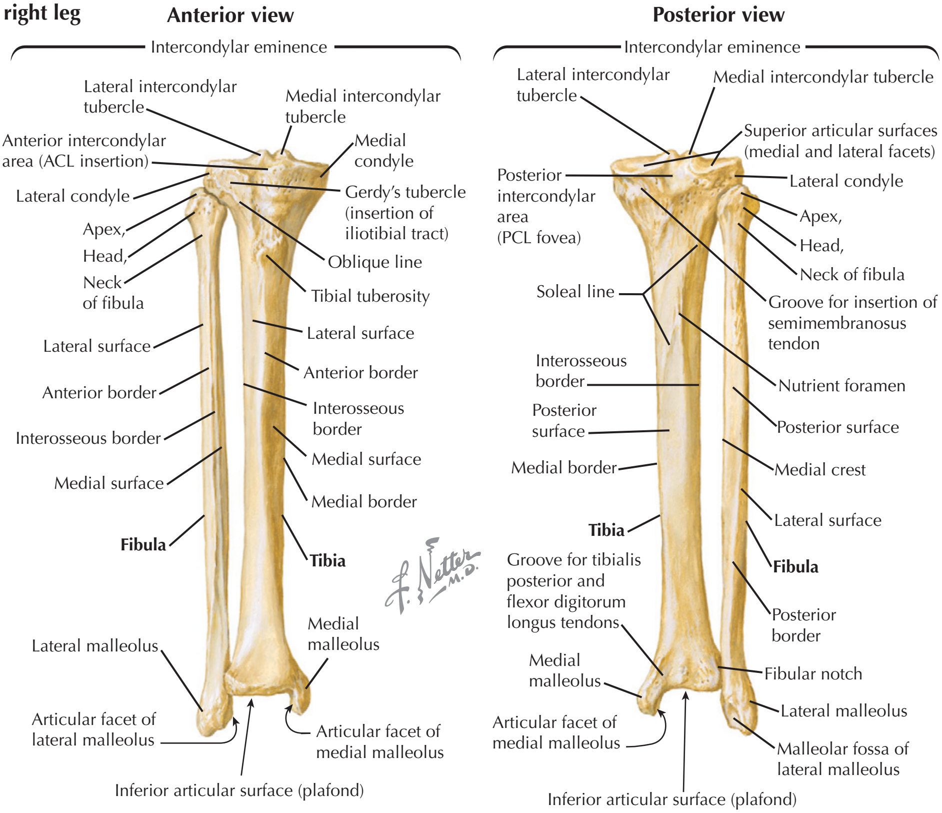

Lateral epicondyle
Adductor tubercle
Medial epicondyle
Lateral epicondyle
Lateral condyle
Medial condyle
Lateral condyle
Lateral condyle
Trochlear groove
Intercondylar fossa


Superior pole
Odd facet
Lateral facet
Medial facet
Inferior pole
Anterior
Medial facet
Posterior
Lateral facet

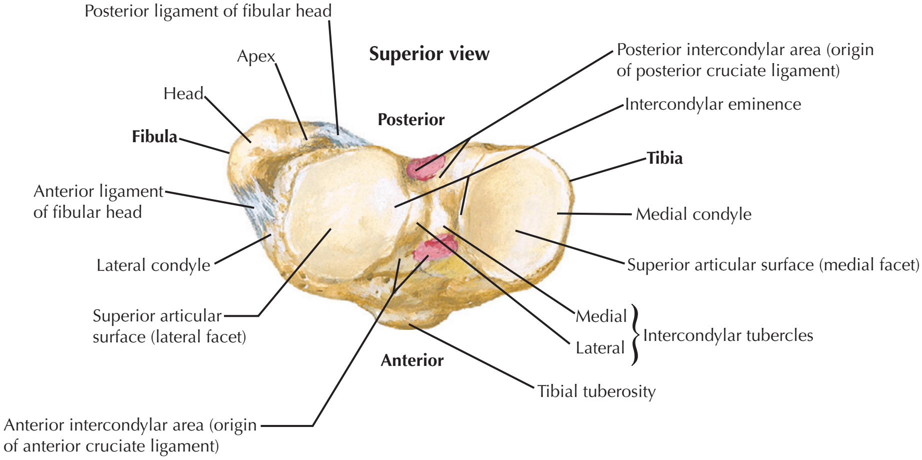
Anterior view **Posterior view** **Superior view**

CHARACTERISTICS	OSSIFY	FUSE	COMMENTS
DISTAL FEMUR			
• Distal femur—2 condyles ◦ Medial: larger, more posterior ◦ Lateral: more ant. & proximal • Trochlear groove: a depression between the condyles anteriorly for patella articulation • Intercondylar notch: between condyles, site of cruciate origins	**Secondary** Distal physis Birth	19yr	• Condyles: rounded posteriorly (for flexion) and flat anteriorly (for standing) ◦ Epicondyle: origin of collateral ligaments ◦ Epicondylar axis and/or post. condylar axis used to determine femur rotation (e.g., in TKA) • Sulcus terminale: groove in lateral condyle. Inferior to groove, it is weight-bearing portion of condyle. • Adductor tubercle: insertion of adductor magnus • Distal femoral physis: grows approx. 7mm/yr
PATELLA			
• Ovoid shaped, inf. & sup. poles • Triangular in cross section • 2 facets (larger lateral & medial) separated by a central ridge ◦ Each facet is subdivided into superior, middle, inferior facets ◦ Odd facet (7th sub-facet) is far medial on medial facet	**Primary** 3yr (single center)	11-13yr	• Largest sesamoid bone in body • Bipartite patella: failure of superolateral portion to fuse. It is often confused with a fracture. • Functions: 1. Enhances quadriceps pull (as fulcrum); 2. Protects knee; 3. Enhances knee lubrication • Contact point on patella moves proximally w/flexion • Odd facet articulates in deep flexion • Has thickest articular cartilage (up to 5mm)

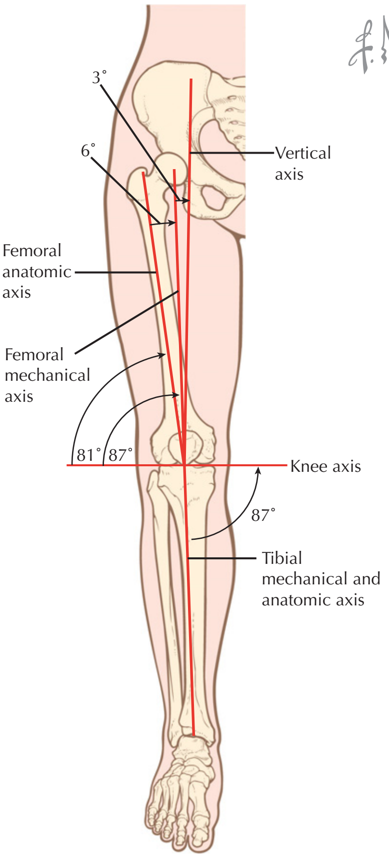
Bones of right leg


Anterior view
Intercondylar eminence
Lateral intercondylar tubercle
Medial intercondylar tubercle
Anterior intercondylar area (ACL insertion)
Medial condyle
Lateral condyle
Gerdy's tubercle (insertion of iliotibial tract)
Apex,
Head,
Neck of fibula
Oblique line
Tibial tuberosity
Lateral surface
Lateral surface
Anterior border
Anterior border
Interosseous border
Interosseous border
Medial surface
Medial surface
Medial border
Fibula
Tibia
Medial malleolus
Lateral malleolus
Articular facet of lateral malleolus
Articular facet of medial malleolus
Inferior articular surface (plafond)
Posterior view
Intercondylar eminence
Lateral intercondylar tubercle
Medial intercondylar tubercle
Superior articular surfaces (medial and lateral facets)
Posterior intercondylar area (PCL fovea)
Lateral condyle
Apex,
Head,
Neck of fibula
Soleal line
Groove for insertion of semimembranosus tendon
Interosseous border
Nutrient foramen
Posterior surface
Posterior surface
Medial border
Medial crest
Lateral surface
Tibia
Fibula
Groove for tibialis posterior and flexor digitorum longus tendons
Posterior border
Medial malleolus
Fibular notch
Lateral malleolus
Articular facet of medial malleolus
Malleolar fossa of lateral malleolus
Inferior articular surface (plafond)

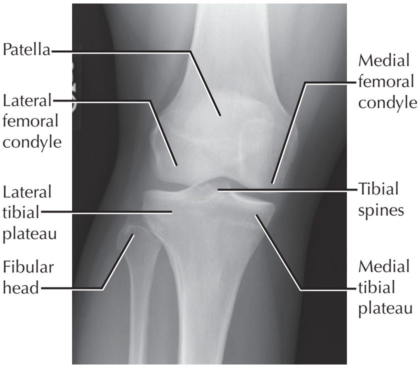
CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
	TIBIA			
• Long bone characteristics • Proximal end: plateau (canc.) ∘ Medial plateau: concave ∘ Lateral plateau: convex ∘ 7-10° posterior slope • Tubercle: 3cm below joint line • Eminence: medial & lateral tubercles (spines) • Shaft: triangular cross section • Distal end: pilon (cancellous) ∘ Articular surface: plafond ∘ Distal tip: medial malleolus	**Primary:** Shaft	7wk (fetal)	18 yr	• Lateral plateau fx more common • Osgood-Schlatter: traction apophysitis at open tibial tubercle apophysis • Tubercle: patellar tendon insertion • IM nail insertion point proximal to tibial tubercle • Tibial spine avulsion fx of ACL (peds) • Gerdy's tubercle on proximal tibia: insertion site of iliotibial tract (band) • Fibularis incisura: lat. groove for fibula • Plafond is roof and medial malleolus is medial wall of ankle mortise
	Secondary 1. Proximal epiphysis 2. Distal epiphysis 3. Tibial tuberosity	 9mo 1yr	18-20yr	
	FIBULA			
• Long bone characteristics • Proximal end: head ∘ Neck • Shaft: long, cylindrical • Distal end: lateral malleolus	**Primary:** Shaft	7wk (fetal)	20yr	• LCL & biceps femoris insert on head • Neck has groove for peroneal nerve • Nerve can be injured in fibula fx • Shaft used for vascularized BG • Lat. mal. is lat. wall of ankle mortise
	Secondary 1. Proximal epiphysis 2. Distal epiphysis	 1-3yr 4yr	18-22yr	


Superior view
Posterior ligament of fibular head
Apex
Head
Fibula
Anterior ligament of fibular head
Lateral condyle
Superior articular surface (lateral facet)
Anterior intercondylar area (origin of anterior cruciate ligament)
Posterior
Anterior
Posterior intercondylar area (origin of posterior cruciate ligament)
Intercondylar eminence
Tibia
Medial condyle
Superior articular surface (medial facet)
Medial
Lateral
Intercondylar tubercles
Tibial tuberosity

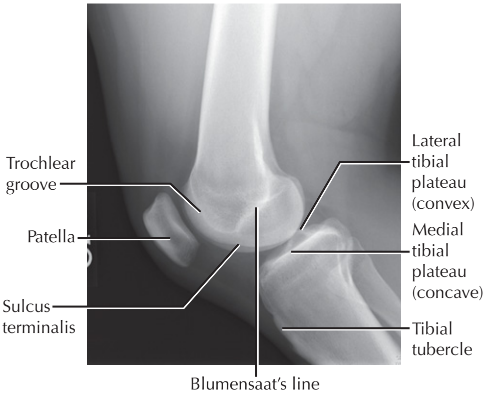
LOWER EXTREMITY ALIGNMENT	
Definitions	
Anatomic axis of femur	Line drawn along the axis of the femur
Anatomic axis of tibia	Line drawn along the axis of the tibia
Mechanical axis of femur	Line drawn between center of femoral head and intercondylar notch
Mechanical axis of tibia	Line drawn between center of knee and center of ankle mortise
Knee axis	Line drawn along inferior aspect of both femoral condyles
Vertical axis	Vertical line, perpendicular to the ground
Lateral distal femoral angle	Angle formed between knee axis and femoral axis laterally
Medial tibial angle	Angle formed between knee axis and tibial axis
Relationships	
Knee axis	Parallel to the ground and perpendicular to vertical axis
Mechanical axis of femur	Average of 6° from anatomic axis Approximately 3° from vertical axis
Mechanical axis of tibia	Normally same as anatomic axis of tibia unless tibia has a deformity
Lateral distal femoral angle	81° from femoral anatomic axis 87° from femoral mechanical axis
Medial proximal tibial angle	87° from tibial mechanical axis


3°
6°
Vertical axis
Femoral anatomic axis
Femoral mechanical axis
81°
87°
Knee axis
87°
Tibial mechanical and anatomic axis

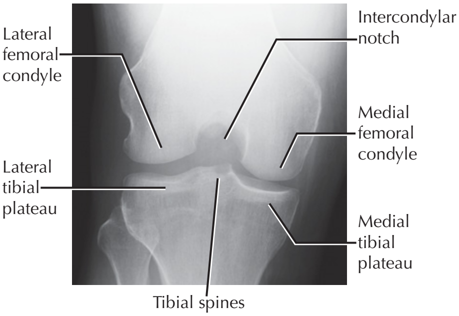
AP radiograph of knee


Patella
Lateral femoral condyle
Lateral tibial plateau
Fibular head
Medial femoral condyle
Tibial spines
Medial tibial plateau

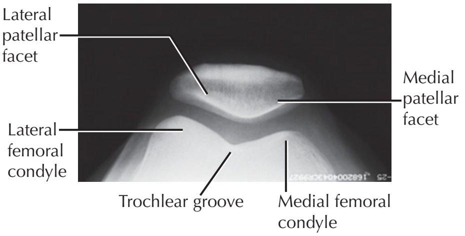
Lateral radiograph of knee


Trochlear groove
Patella
Sulcus terminalis
Lateral tibial plateau (convex)
Medial tibial plateau (concave)
Tibial tubercle
Blumensaat's line

Notch radiograph

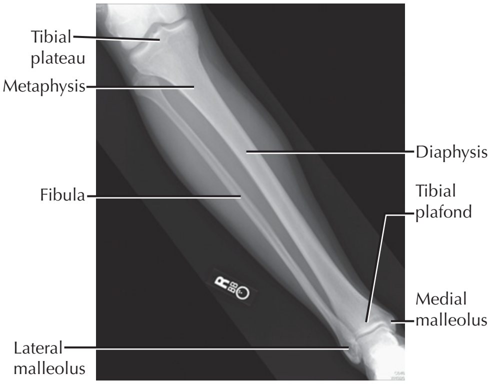

Lateral femoral condyle
Lateral tibial plateau
Intercondylar notch
Medial femoral condyle
Medial tibial plateau
Tibial spines

Sunrise radiograph

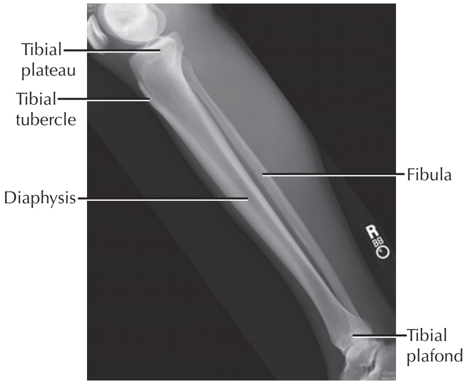

Lateral patellar facet
Lateral femoral condyle
Medial patellar facet
Trochlear groove
Medial femoral condyle

RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
		KNEE	
AP	Supine; beam at 90°	Medial/lateral compartments; varus/valgus deformity	Femoral condyle, tibial plateau/spine, patella fx, OCD, osteoarthritis (weight-bearing)
Lateral	Supine; 30° flexion	Patellofemoral compartment	Fractures, quadriceps/patellar tendon rupture
Axial/sunrise	Prone; knee 115° flex; beam at patella 15° cephalad	Patellofemoral compartment (patellar articular facets)	Patellofemoral arthritis, malalignment or patellar tilt
Tunnel/notch	Prone; knee 45° flex; beam is caudal at knee joint	Posterior femoral condyles, intercondylar notch, tibial eminence	Osteochondral fx/defect, femoral condyle or tibial eminence fx, DJD/osteoarthritis
Merchant	Supine; legs of table at 45°; beam at PF joint	Patellofemoral compartment (patellar articular facets)	Articular surface lesions, DJD, tilt or malalignment
Rosenberg	PA (weight-bearing); knees at 45°	Medial/lateral compartments	Osteoarthritis of WB portion of posterior condyles

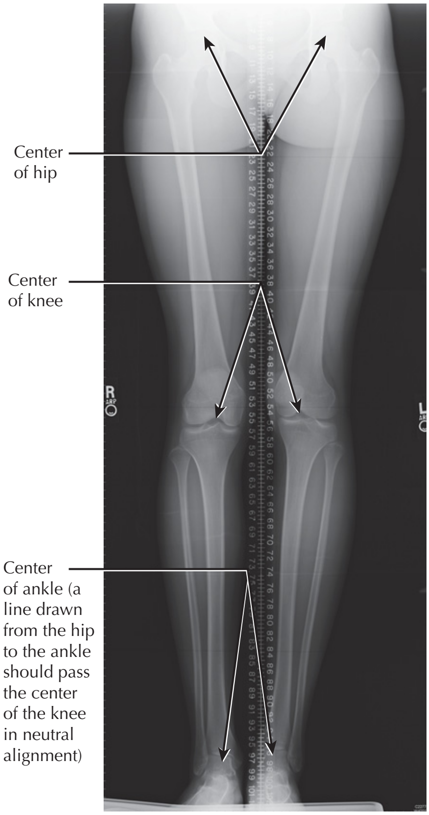
AP radiograph


Tibial plateau
Metaphysis
Fibula
Lateral malleolus
Diaphysis
Tibial plafond
Medial malleolus

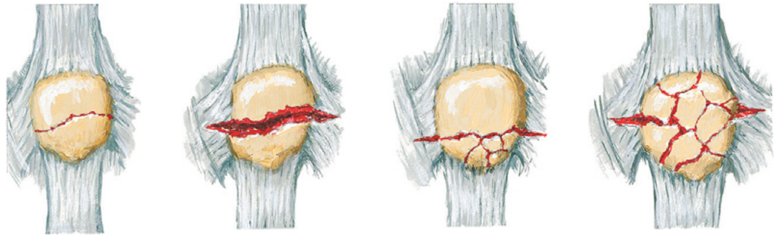
Lateral radiograph


Tibial plateau
Tibial tubercle
Diaphysis
Fibula
Tibial plafond

Alignment radiograph


Center of hip
Center of knee
Center of ankle (a line drawn from the hip to the ankle should pass the center of the knee in neutral alignment)

RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
LEG			
AP tibia	Supine; beam at mid tibia	Tibia and surrounding soft tissues	Fractures, deformity, infection, etc
Lateral tibia	Supine; beam laterally mid-tibia	Tibia and surrounding soft tissues	Fractures, deformity, infection, etc
See Foot & Ankle chapter to see views of the ankle.			
OTHER STUDIES			
Alignment films	Bilateral full length hip to ankle, WB	Full lower extremity alignment	Determine malalignment/deformity
Scanogram	Entire bilateral LE with ruler	Measure length of bones	Used for leg length discrepancy
CT	Axial, coronal, & sagittal views	Articular congruity, fracture fragments	Intraarticular condyle, plateau, pilon fxs
MRI	Sequence protocols vary	Soft tissues: ligaments, meniscus, articular cartilage, bone marrow	Ligament ruptures, meniscal tears, OCD, stress fxs, tumor, infection
Bone scan	Radioisotope	All bones evaluated	Stress fxs, infection, tumor



Fracture of Patella

Nondisplaced transverse fracture with intact retinacula

Displaced transverse fracture with tears in retinacula

Transverse fracture with comminution of distal pole

Severely comminuted fracture

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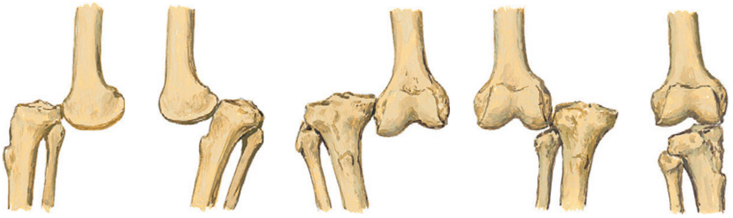


Dislocation of Knee Joint
Types of dislocation

Anterior

Posterior

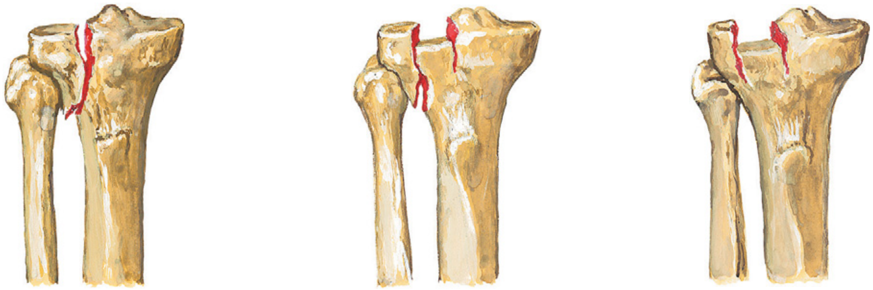
Lateral

Medial

Rotational

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
PATELLAR FRACTURE			
• Mechanism: direct & indirect: e.g., fall, dashboard, etc. • Pull of quadriceps and tendons displace most fxs • If intact, retinaculum resists displacement of fragments • Do not confuse with bipartite patella (unfused superolateral corner)	**Hx:** Trauma, pain, cannot extend knee, swelling **PE:** "Dome" effusion, tenderness, +/– palpable defect, inability to extend knee **XR:** Knee trauma series **CT:** Not usually needed, will show fx fragments	Descriptive/location: ◦ Nondisplaced ◦ Transverse ◦ Vertical ◦ Stellate ◦ Inferior/superior pole ◦ Comminuted	• Nondisplaced or comminuted—knee brace/cast 6-8 wk, ROM • Displaced (>2-3mm): ORIF (e.g., tension bands) to restore articular surface • Severely comminuted: may require full or partial patellectomy
COMPLICATIONS: Osteoarthritis and/or pain, decreased motion and/or strength, osteonecrosis, refracture			
KNEE DISLOCATION			
• Rare: ortho. emergency • Usually high-energy injury • Multiple ligaments & other soft tissue are disrupted • High incidence of associated fx & neurovascular injury • Many spontaneously reduce; must keep index of suspicion for injury • Close follow-up is important for good result	**Hx:** Trauma, pain, inability to bear weight **PE:** Large effusion, soft tissue swelling, deformity, pain, +/– distal pulses/ peroneal nerve function **XR:** AP/lateral **AGRAM:** Evaluate for arterial injury **MR:** Ligament injury, meniscus, articular cartilage injury	By position: ◦ Anterior ◦ Posterior ◦ Lateral ◦ Medial ◦ Rotatory: anteromedial or anterolateral	• Early reduction essential; postreduction neurologic exam and x-rays • Immobilize (cast) 6-8wk (if ligaments not torn) • Surgery if irreducible or vascular injury (revascularize within 6 hr + fasciotomy). • Early vs. delayed ligament repair/ reconstruction
COMPLICATIONS: Neurovascular: popliteal artery, peroneal nerve injury, knee stiffness (#1), chronic instability			

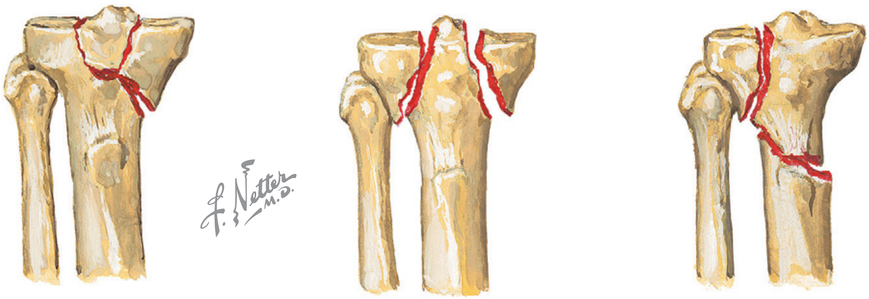
Tibial Plateau Fracture



I. Split fracture of lateral tibial plateau

II. Split fracture of lateral condyle plus depression of tibial plateau

III. Depression of lateral tibial plateau without split fracture



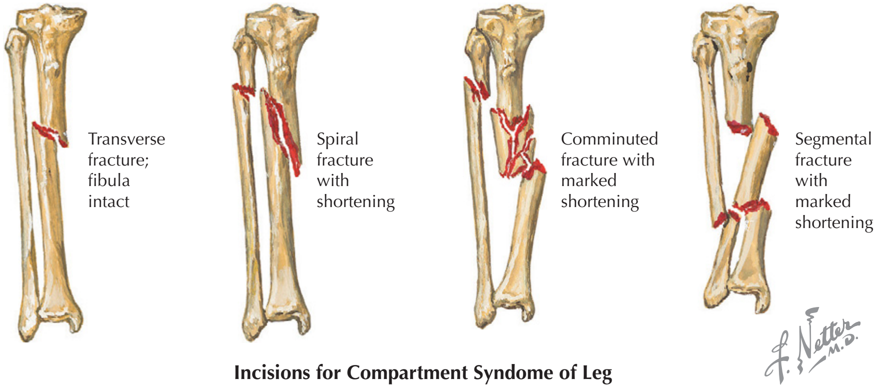
IV. Comminuted split fracture of medial tibial plateau and tibial spine

V. Biocondylar fracture involving both tibial plateaus with widening

VI. Fracture of lateral tibial plateau with separation of metaphyseal-diaphyseal junction

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
TIBIAL PLATEAU FRACTURE			
• Mechanism: axial load AND varus/valgus stress • Restoration of articular surface/congruity is important • Metaphyseal injury: bone will compress, leading to functional bone loss; may need bone graft • Lateral fracture more common than medial • Associated meniscal (50%) and ligament (MCL>ACL) tears	**Hx:** Trauma, pain, swelling, inability to bear weight **PE:** Effusion, tenderness; do thorough neurovascular exam. **XR:** Knee trauma series **CT:** To better define fx lines & comminution. Needed for preop planning. **AGRAM:** If decreased pulses. Consider in all type IV fxs	**Schatzker (6 types):** I: Lateral plateau split fx II: Lat. split/depression fx III: Lat. plateau depression IV: Medial plat. split fx V: Bicondylar plateau fx VI: Fx w/metaphyseal-diaphyseal separation Types IV-VI usually result from high-energy trauma	• Consider joint aspiration • Nondisplaced (<3mm step off, <5mm gapping): knee brace/cast 6-8wk, NWB 6-12wk • Displaced: ORIF +/– bone graft (plates & screws). Early ROM but NWB 12wk • Avoid both medial & lateral periosteal stripping (incr. nonunion rate) • Repair torn ligaments/menisci
COMPLICATIONS: compartment syndrome, posttraumatic osteoarthritis, persistent knee pain, popliteal artery injury			

Fracture of Shaft of Tibia


Transverse fracture; fibula intact
Spiral fracture with shortening
Comminuted fracture with marked shortening
Segmental fracture with marked shortening
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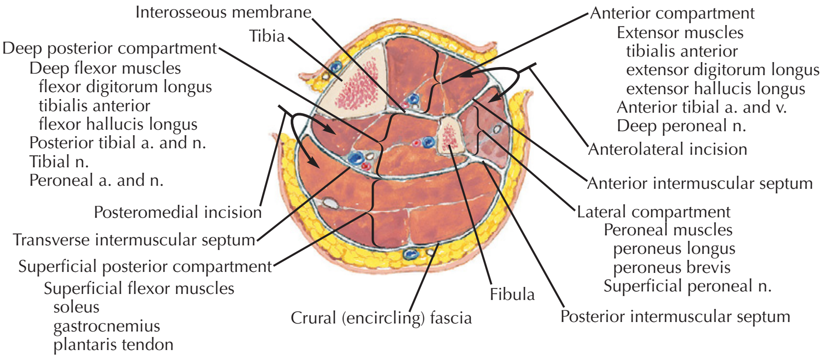
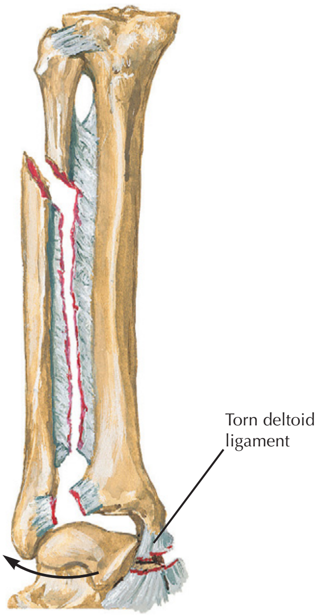
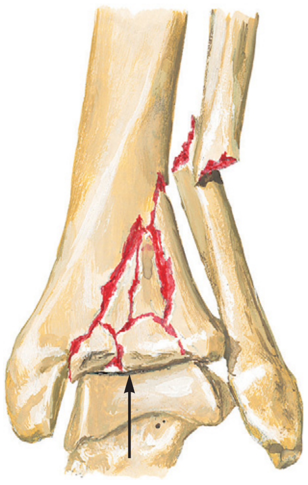
Incisions for Compartment Syndome of Leg


Interosseous membrane
Tibia
Deep posterior compartment
Deep flexor muscles
flexor digitorum longus
tibialis anterior
flexor hallucis longus
Posterior tibial a. and n.
Tibial n.
Peroneal a. and n.
Posteromedial incision
Transverse intermuscular septum
Superficial posterior compartment
Superficial flexor muscles
soleus
gastrocnemius
plantaris tendon
Crural (encircling) fascia
Fibula
Anterior compartment
Extensor muscles
tibialis anterior
extensor digitorum longus
extensor hallucis longus
Anterior tibial a. and v.
Deep peroneal n.
Anterolateral incision
Anterior intermuscular septum
Lateral compartment
Peroneal muscles
peroneus longus
peroneus brevis
Superficial peroneal n.
Posterior intermuscular septum

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
TIBIA SHAFT FRACTURE			
• Common long bone fx • Usually high-E trauma • Condition of surrounding soft tissues is critically important to success of outcome • Compartment syndrome: consider in ALL fxs • Subcutaneous position of tibia predisposes it to open fractures • May lead to amputation	**Hx:** Trauma, pain, swelling, inability to bear weight **PE:** Swelling, deformity, +/− firm/tense compartments **XR:** AP & lateral of tib./fib. (also knee & ankle series) **CT:** Not usually needed **AGRAM:** If decreased pulses	**Descriptive:** Location Displaced/comminuted Type: transverse, spiral oblique Rotation/angulation	• Nondisplaced: long leg cast 8wk (best for pediatrics, seldom used in adults) • Displaced/unstable: reamed, locked IM nail • Open fractures: thorough I&D is critical. External fixation is useful for these fractures. • Fasciotomies for compartment syndrome
COMPLICATIONS: compartment syndrome, nonunion & malunion, knee pain (from IM nail), ankle and/or knee stiffness			
COMPARTMENT SYNDROME			
• Incr. pressure in closed space/compartment • Compartments (4): have rigid fibroosseous borders • Mechanism: trauma (fracture, crush) vascular injury, burn	**Hx:** Trauma, pain **PE:** 5 P's: pain (w/passive stretch), paresthesia, pallor, pulseless, paralysis Firm/tense compartments	**XR:** Evaluate for fractures **Angiogram:** If needed to evaluate for vascular inj. **Compartment Pressures:** 1. Absolute: >30-40mmHg 2. ΔP: <30mmHg of diastolic blood pressure	• Usually a clinical diagnosis • Emergent fasciotomy (usually two incisions)



Maisonneuve fracture
Complete disruption of tibiofibular syndesmosis with diastasis caused by external rotation of talus and transmission of force to proximal fibula, resulting in high fracture of fibula. Interosseous membrane torn longitudinally. Radiograph shows repair with long transverse screw (these fractures easily missed on radiographs)



Pilon fracture
Usual cause is vertical loading of ankle joint, eg, falling from height and landing on heel (usually with ankle dorsiflexed). Fracture and compression of articular surface of tibia plus separation of malleoli and fracture of fibula

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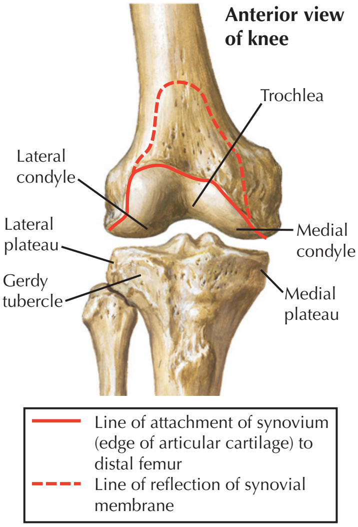
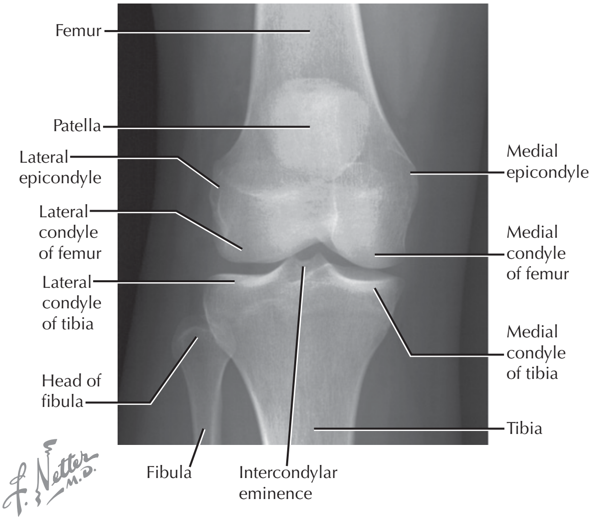
DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
MAISONNEUVE FRACTURE			
• Complete syndesmosis disruption with diastasis & proximal fibula fx • Variant of ankle fracture & deltoid ligament rupture • Unstable fracture	**Hx:** Trauma, ankle pain, +/– knee pain **PE:** Ankle pain, swelling, proximal fibula tenderness **XR:** Leg and ankle series. May need stress views of ankle to see instability	Descriptive: Location Type: Spiral Oblique Comminuted	Reduce and stabilize syndesmosis (e.g., with a screw); immobilize while healing
COMPLICATIONS: ankle instability, ankle arthritis			
PILON (DISTAL TIBIA) FRACTURE			
• Intraarticular: through distal articular/WB surface • Soft tissue swelling leads to complications with early open treatment • Restoration of articular surface congruity is essential • Healing is often slow	**Hx:** Trauma, cannot bear weight, pain, swelling **PE:** Effusion, tenderness; do good neurovascular exam **XR:** AP/lateral (obliques) **CT:** Needed to better define fx and preop plan	**Ruedi/Allgower** (3 types): I: Non or minimally displaced II: Displaced: articular surface incongruous III: Comminuted articular surface	• Nondisplaced: cast & NWB for 6-12wk • Displaced/comminuted: early external fixation and delayed (14 days) ORIF; (plates & screws +/– bone grafting)
COMPLICATIONS: posttraumatic DJD, (almost 100% in comminuted fxs), stiffness, malunion, wound complications			


Anterior view of knee
Trochlea
Lateral condyle
Lateral plateau
Gerdy tubercle
Medial condyle
Medial plateau
— Line of attachment of synovium (edge of articular cartilage) to distal femur
- - - Line of reflection of synovial membrane


Femur
Patella
Lateral epicondyle
Lateral condyle of femur
Lateral condyle of tibia
Head of fibula
Fibula
Intercondylar eminence
Tibia
Medial condyle of tibia
Medial condyle of femur
Medial epicondyle
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KNEE

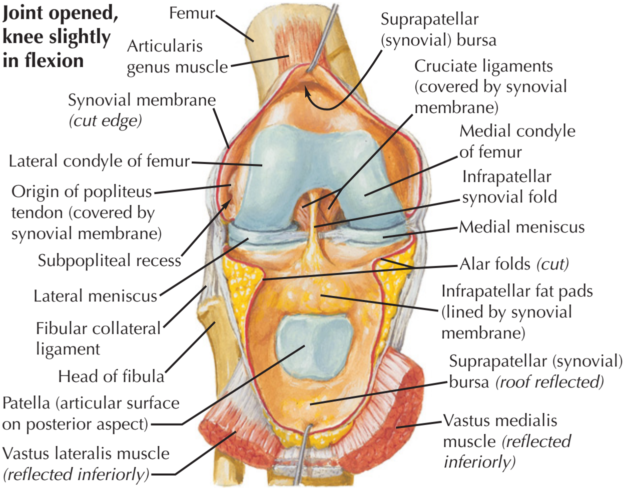
Structure

- Comprises 3 separate articulations
  - Medial & lateral femorotibial joints (2)—condyloid (hinge) joints. Femoral condyles articulate with corresponding tibial plateaus.
  - Patellofemoral joint (1)—sellar (gliding) joint. Patella articulates with femoral trochlear groove.
- 3 compartments in the knee: medial, lateral, patellofemoral
- Capsule surrounds entire joint (all three articulations/compartments) and extends proximally into the suprapatellar pouch.
  - The capsule has a synovial lining that also covers the cruciate ligaments (making them intraarticular but extrasynovial)
- Articular (hyaline) cartilage (type II collagen) covers the femoral condyles, tibial plateaus, trochlear groove, and patellar facets.
- Menisci are interposed in the medial & lateral femorotibial joints to: 1.protect the articular cartilage, 2. give support to the knee.
- Knee axis (line drawn between weight-bearing portion of medial & lateral femoral condyles) is parallel to the ground.
  - Mechanical axis of the femur is 3° valgus to the vertical axis, allowing the larger MFC to align with the LFC parallel to the ground.
  - Mechanical axis of the tibia is 3° varus to the vertical axis (87° to knee axis).

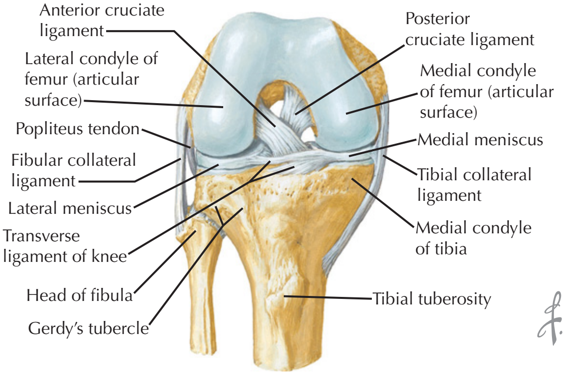
Kinematics

- Inherently unstable joint. Bony morphology adds little stability. Stability primarily provided by surrounding static and dynamic stabilizers. (Dynamic stabilizers may compensate when static stabilizers are injured [e.g., complete or partial ACL rupture].)
  - Medial: Static—superficial and deep medial collateral ligaments (MCL), posterior oblique ligament (POL).
    Dynamic—semimembranosus, vastus medialis, medial gastrocnemius, PES tendons
  - Lateral: Static—lateral collateral ligament (LCL), iliotibial band (ITB), arcuate ligament.
    Dynamic—popliteus, biceps femoris, lateral gastrocnemius
- Not a simple hinge joint. The knee has 6 degrees of motion:
  - Extension/flexion, IR/ER, varus/valgus, anterior/posterior translation, medial/lateral translation, compression/distraction
- Flexion & extension are the primary motions in the knee.
  - Flexion is a combination of both “rolling” and “sliding” of the femur on the tibia in varying ratios depending on the degree of flexion.
  - Rolling: equal translation of tibiofemoral contact point & joint axis. Rolling predominates in early flexion.
  - Gliding: translation of tibiofemoral contact point without moving the joint axis. Increased gliding is needed for deep flexion.
  - The cruciate ligaments control the roll/glide function. The PCL alone can maintain this function (e.g., PCL retaining TKA).
  - Normal motion: Extension/flexion: −5 to 140°. 115° needed to get out of a chair; 130° needed for fast running.
- IR/ER: about 10° total through arc of motion. Tibia IRs in swing, and ERs in stance via “screw home mechanism.”
  - Screw home mechanism: larger MFC ERs tibia in full extension, tightening cruciates and stabilizing the knee in stance.
  - Popliteus IRs the tibia to “unlock” the knee, loosen the cruciates, which allows the knee to initiate flexion.
- Other motions: Medial/lateral translation: minimal in normal knees
  - Anterior/posterior translation: dependent on tissue laxity, usually within 2mm of contralateral side in normal knees
  - Varus/valgus: approximately 5mm of gapping laterally or medially when stressed in normal knees

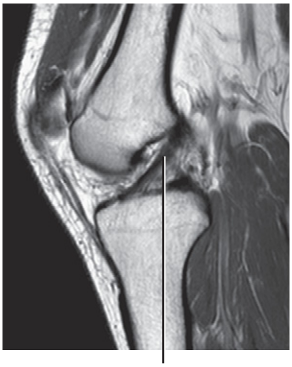
Joint opened, knee slightly in flexion


Femur
Articularis genus muscle
Synovial membrane *(cut edge)*
Lateral condyle of femur
Origin of popliteus tendon (covered by synovial membrane)
Subpopliteal recess
Lateral meniscus
Fibular collateral ligament
Head of fibula
Patella (articular surface on posterior aspect)
Vastus lateralis muscle *(reflected inferiorly)*
Suprapatellar (synovial) bursa
Cruciate ligaments (covered by synovial membrane)
Medial condyle of femur
Infrapatellar synovial fold
Medial meniscus
Alar folds *(cut)*
Infrapatellar fat pads (lined by synovial membrane)
Suprapatellar (synovial) bursa *(roof reflected)*
Vastus medialis muscle *(reflected inferiorly)*

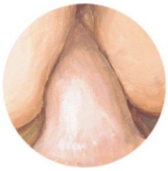
Right knee in flexion: anterior view


Anterior cruciate ligament
Lateral condyle of femur (articular surface)
Popliteus tendon
Fibular collateral ligament
Lateral meniscus
Transverse ligament of knee
Head of fibula
Gerdy's tubercle
Posterior cruciate ligament
Medial condyle of femur (articular surface)
Medial meniscus
Tibial collateral ligament
Medial condyle of tibia
Tibial tuberosity

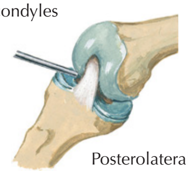
MRI



Intercondylar notch

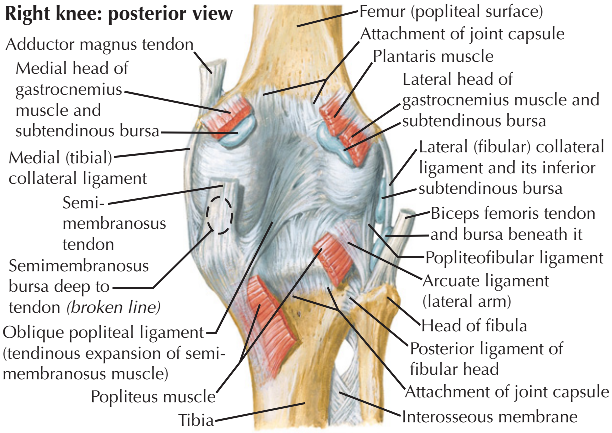


Anterior cruciate ligament visualized between femoral condyles

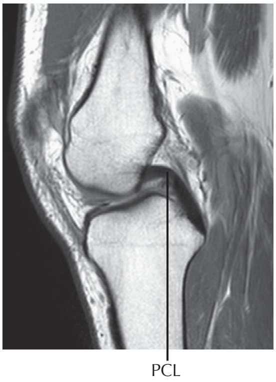

Posterolateral

LIGAMENTS	ATTACHMENTS	FUNCTION/COMMENT
KNEE		
Femorotibial Joint—Anterior Structures		
Anterior cruciate ligament (ACL) Anteromedial bundle Posterolateral bundle	Posteromedial aspect of lateral femoral condyle to anterior tibial eminence	Primary restraint to anterior tibial translation; secondary restraint to varus (in extension) & IR Tight in knee flexion, lax in extension Tight in knee extension, lax in flexion
Transverse meniscal ligament	Connects both anterior horns of menisci to tibia	Stabilizes menisci; can be torn/injured
Other Structures		
Ligamentum mucosum (anterior plica)	Distal femoral articulation to anterior tibial plateau	Synovial remnant. Covers anterior notch (ACL); may need to be debrided for full visualization
Infrapatellar fat pad	Posterior to patellar tendon, anterior to intercondylar notch	Cushions patellar tendon. Can become fibrotic or impinged on, causing knee pain (Hoffa syndrome)
See Patellofemoral Joint for other anterior structures		

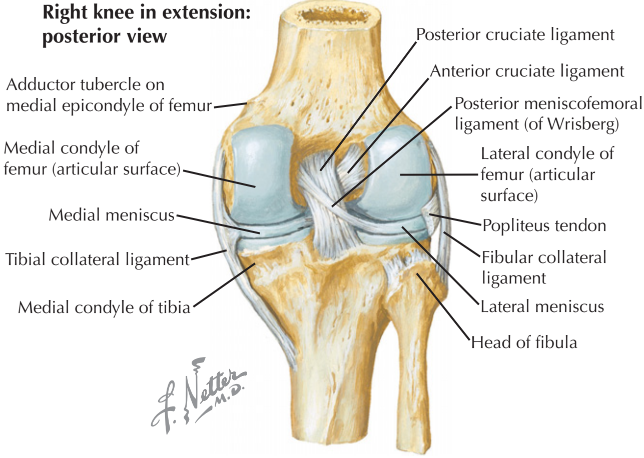
Right knee: posterior view


Adductor magnus tendon
Medial head of gastrocnemius muscle and subtendinous bursa
Medial (tibial) collateral ligament
Semi-membranosus tendon
Semimembranosus bursa deep to tendon (broken line)
Oblique popliteal ligament (tendinous expansion of semi-membranosus muscle)
Popliteus muscle
Tibia
Femur (popliteal surface)
Attachment of joint capsule
Plantaris muscle
Lateral head of gastrocnemius muscle and subtendinous bursa
Lateral (fibular) collateral ligament and its inferior subtendinous bursa
Biceps femoris tendon and bursa beneath it
Popliteofibular ligament
Arcuate ligament (lateral arm)
Head of fibula
Posterior ligament of fibular head
Attachment of joint capsule
Interosseous membrane

MRI



Right knee in extension: posterior view


Adductor tubercle on medial epicondyle of femur
Medial condyle of femur (articular surface)
Medial meniscus
Tibial collateral ligament
Medial condyle of tibia
Posterior cruciate ligament
Anterior cruciate ligament
Posterior meniscofemoral ligament (of Wrisberg)
Lateral condyle of femur (articular surface)
Popliteus tendon
Fibular collateral ligament
Lateral meniscus
Head of fibula
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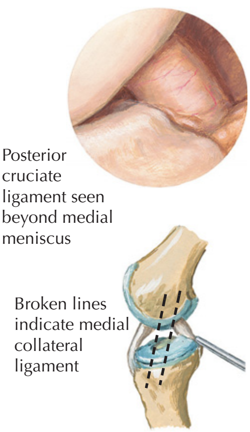
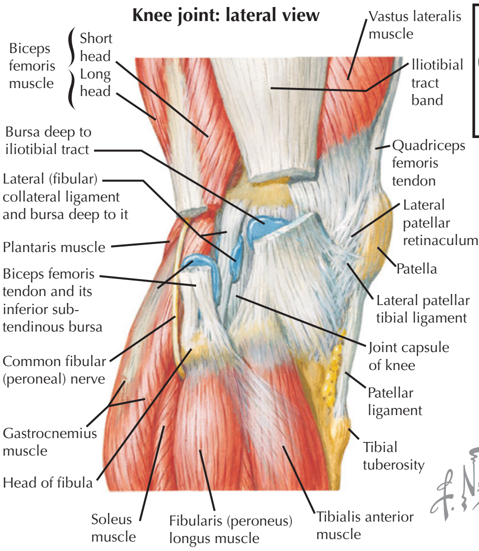
Posteromedial compartment


Posterior cruciate ligament seen beyond medial meniscus
Broken lines indicate medial collateral ligament

LIGAMENTS	ATTACHMENTS	COMMENTS
KNEE		
Femorotibial Joint—Posterior Structures		
Posterior cruciate ligament (PCL)	Lateral aspect (in notch) of medial femoral condyle to post. proximal tibia (below joint line)	Primary restraint to posterior tibial translation Secondary restraint to varus, valgus, and ER
Anterolateral bundle	Ant. origin on condyle, lat. on tibia	Tight in knee flexion, lax in extension
Posteromedial bundle	Post. origin on condyle, med. on tibia	Tight in knee extension, lax in flexion
Meniscofemoral ligaments	Posterior lateral meniscus to MFC and/or PCL, either:	Variably present. Rarely are both present
Ligament of Humphrey	Anterior to PCL	Contributes to PCL function & stabilizes meniscus
Ligament of Wrisberg	Posterior to PCL	Contributes to PCL function & stabilizes meniscus
Oblique popliteal ligament (OPL)	Origin on semimembranosus insertion on posterior tibia; inserts on posterior LFC & capsule	Tightens posterior capsule when semimembranosus contracts; considered part of "posteromedial" corner


Knee joint: lateral view

Biceps femoris muscle
Short head
Long head
Bursa deep to iliotibial tract
Lateral (fibular) collateral ligament and bursa deep to it
Plantaris muscle
Biceps femoris tendon and its inferior sub-tendinous bursa
Common fibular (peroneal) nerve
Gastrocnemius muscle
Head of fibula
Soleus muscle
Fibularis (peroneus) longus muscle
Tibialis anterior muscle
Vastus lateralis muscle
Iliotibial tract band
Quadriceps femoris tendon
Lateral patellar retinaculum
Patella
Lateral patellar tibial ligament
Joint capsule of knee
Patellar ligament
Tibial tuberosity
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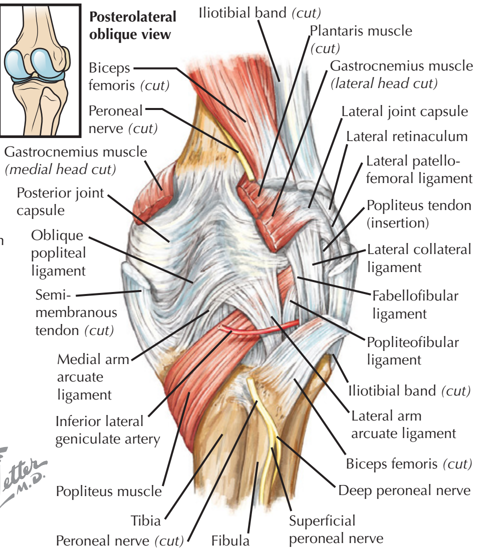
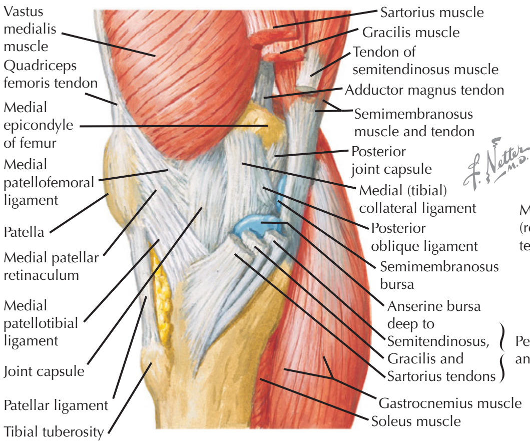

Posterolateral oblique view

Biceps femoris (cut)
Peroneal nerve (cut)
Gastrocnemius muscle (medial head cut)
Posterior joint capsule
Oblique popliteal ligament
Semi-membranous tendon (cut)
Medial arm arcuate ligament
Inferior lateral geniculate artery
Popliteus muscle
Tibia
Peroneal nerve (cut)
Fibula
Iliotibial band (cut)
Plantaris muscle (cut)
Gastrocnemius muscle (lateral head cut)
Lateral joint capsule
Lateral retinaculum
Lateral patello-femoral ligament
Popliteus tendon (insertion)
Lateral collateral ligament
Fabellofibular ligament
Popliteofibular ligament
Iliotibial band (cut)
Lateral arm arcuate ligament
Biceps femoris (cut)
Deep peroneal nerve
Superficial peroneal nerve

LIGAMENTS	ATTACHMENTS	FUNCTION/COMMENT
KNEE		
Femorotibial Joint—Lateral and Posterolateral Structures		
First Layer—Superficial		
Iliotibial band (tract) (ITB)	3 insertions: 1. Gerdy's tubercle, 2. patella and patellar tendon, 3. supracondylar tubercle	Stabilizes lateral knee—"accessory anterolateral ligament." Post. in flexion (ERs tibia), ant. in extension
Biceps femoris	2 heads insert on fibular head, lateral to LCL	Lateral stabilizer, also externally rotates tibia
Second Layer—Middle		
Lateral patellofemoral ligament Lateral patellar retinaculum	Lateral femur to lateral edge of patella Vastus fascia to tibia & patella	May need release if tightened and causing patella tilt and abnormal lateral articular cartilage wear
Third Layer—Deep		
SUPERFICIAL LAMINA		
Lateral collateral lig. (LCL)	Lateral epicondyle to medial fibular head	Primary restraint to varus stress, also resists ER
Fabellofibular ligament	Fibula head to fabella, usually with arcuate lig.	Variably present, also called "short collateral"
DEEP LAMINA		
Popliteus muscle and tendon	Inserts anterior and distal to LCL origin	Resists tibia ER, varus, and posterior translation
Popliteofibular ligament (PFL)	Popliteus musculotendinous jxn to fibula head	Primary static restraint to external rotation (ER)
Capsule	Femur to tibia. Extends 15mm below joint line	Reinforced by other structures; resists varus & ER
Arcuate ligament	Lateral arm: fibular head to posterior femur Medial arm: post-lat femur, blends with OPL	Variably present, Y-shaped: two arms. Lateral arm covers popliteus supporting posterolateral knee
Other		
Lateral meniscus	To lateral plateau via coronary ligaments	Gives concavity to the convex lateral plateau
Lateral head of gastrocnemius	Origin is on posterior lateral condyle	Adds dynamic support to posterolateral knee

- The inferior lateral geniculate artery passes between the superficial and deep lamina of the third layer of the posterolateral corner.
- The LCL, popliteus, and popliteofibular ligament are the most consistent structures and are the focus of surgical reconstruction.
- Most of the posterolateral structures act as stabilizers to varus & ER forces. They also are secondary stabilizers to posterior translation.
- Arcuate "complex" refers to posterolateral stabilizing structures including: LCL, arcuate ligament, popliteus, & lateral gastrocnemius.


Vastus medialis muscle
Quadriceps femoris tendon
Medial epicondyle of femur
Medial patellofemoral ligament
Patella
Medial patellar retinaculum
Medial patellotibial ligament
Joint capsule
Patellar ligament
Tibial tuberosity
Sartorius muscle
Gracilis muscle
Tendon of semitendinosus muscle
Adductor magnus tendon
Semimembranosus muscle and tendon
Posterior joint capsule
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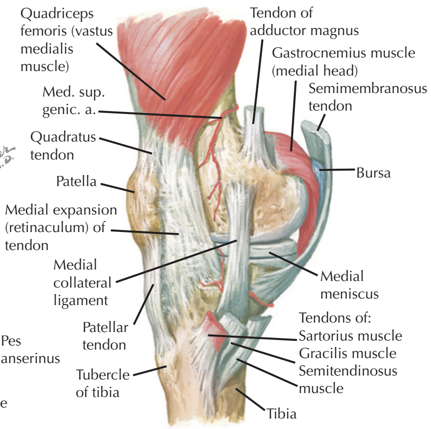
Medial (tibial) collateral ligament
Posterior oblique ligament
Semimembranosus bursa
Anserine bursa deep to Semitendinosus, Gracilis and Sartorius tendons
Pes anserinus
Gastrocnemius muscle
Soleus muscle

Knee joint: medial view

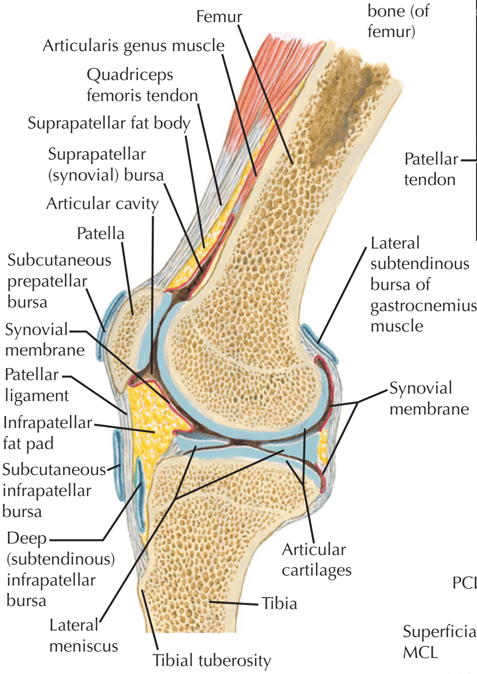

Quadriceps femoris (vastus medialis muscle)
Med. sup. genic. a.
Quadratus tendon
Patella
Medial expansion (retinaculum) of tendon
Medial collateral ligament
Patellar tendon
Tubercle of tibia
Tendon of adductor magnus
Gastrocnemius muscle (medial head)
Semimembranosus tendon
Bursa
Medial meniscus
Tendons of:
Sartorius muscle
Gracilis muscle
Semitendinosus muscle
Tibia

Ligaments of the knee: medial view

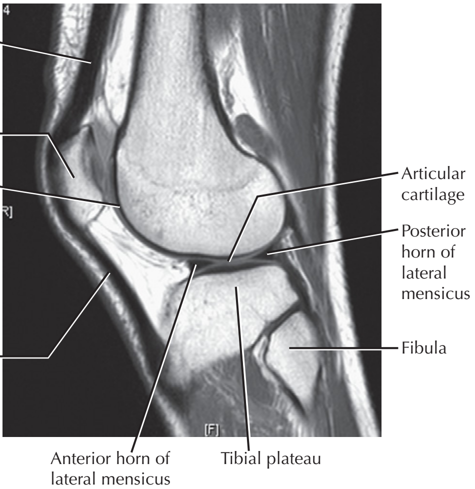
LIGAMENTS	ATTACHMENTS	FUNCTION/COMMENT
KNEE		
Femorotibial Joint—Medial Structures		
First Layer—Superficial		
Sartorius	Becomes fascial layer at insertion at Pes	Covers other tendons at Pes insertion
Fascia	Deep fascia from thigh continues to knee	Blends with retinaculum (ant.) & capsule (post.)
Second Layer—Middle		
Superficial medial collateral (MCL)	Medial epicondyle to tibia (deep to Pes) Broad insertion is 5-7cm below joint line	Primary restraint to valgus force (esp. at 30°) Secondary stabilizer to anterior translation & IR
Posterior oblique ligament (POL)	Adductor tubercle (post. to MCL) to posterior tibia, PH of med. meniscus, & capsule	Static stabilizer against valgus. Lax in flexion but tightens dynamically due to semimembr.
Medial patellofemoral ligament (MPFL)	Medial patella to medial femoral epicondyle	Primary static stabilizer against patella lateralization; may need repair/reconstruction after dx
Medial patellar retinaculum	Continuous w/vastus fascia to tibia & patella	Can also be injured in lateral patellar subluxation
Semimembranosus	Inserts posteromedial on tibia	Gives posteromedial support
Third Layer—Deep		
Deep medial collateral (MCL) Meniscofemoral fibers Meniscotibial fibers	Inserts on medial meniscus & tibia plateau 2 sets of fibers: Femur to meniscus Tibia to meniscus	Stabilizes meniscus. Also known as medial capsular ligament or middle ⅓ capsular ligament
Capsule	Femur to tibia, extends 15mm below joint	Reinforced by other posteromedial structures
Other		
Medial meniscus	Attached firmly to medial tibial plateau via coronary ligaments	Posterior horn is secondary stabilizer to anterior translation. Becomes 1° in ACL
Medial head of gastrocnemius	Origin on the posteromedial femur	Provides some minor additional dynamic support

- Gracilis and semitendinosus tendons are between layers 1 and 2 and act as secondary dynamic medial stabilizers.
- The POL is a confluence of layers 2 and 3 tissues that are indistinct in the posteromedial aspect of the knee.

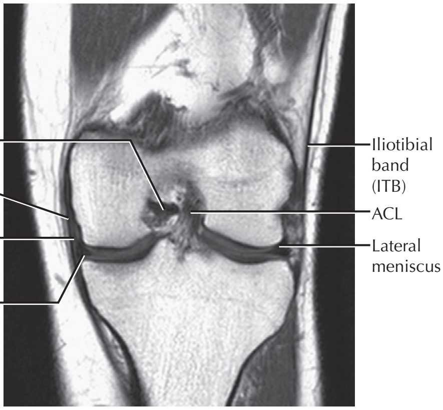
Sagittal section (lateral to midline of knee)

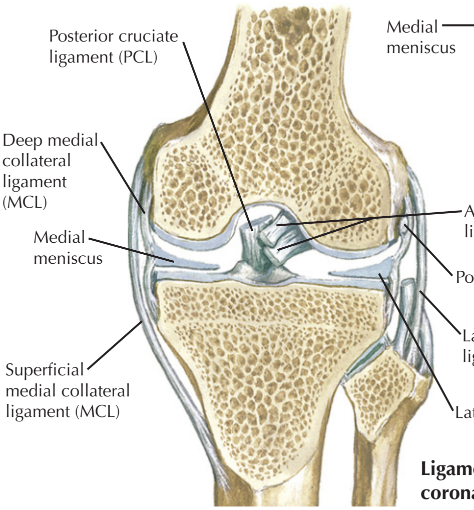

Femur
Articularis genus muscle
Quadriceps femoris tendon
Suprapatellar fat body
Suprapatellar (synovial) bursa
Articular cavity
Patella
Subcutaneous prepatellar bursa
Synovial membrane
Patellar ligament
Infrapatellar fat pad
Subcutaneous infrapatellar bursa
Deep (subtendinous) infrapatellar bursa
Lateral meniscus
Tibial tuberosity
Tibia
Articular cartilages
Synovial membrane
Lateral subtendinous bursa of gastrocnemius muscle

Lateral MRI

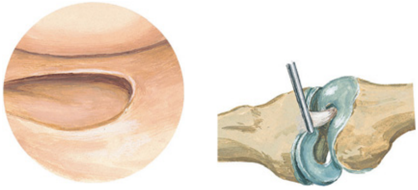

Quadriceps tendon
Patella
Subchondral bone (of femur)
Patellar tendon
Anterior horn of lateral mensicus
Tibial plateau
Articular cartilage
Posterior horn of lateral mensicus
Fibula

Coronal MRI

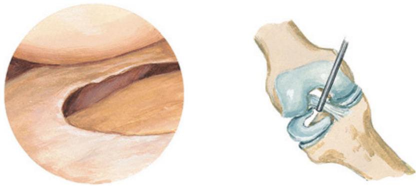

PCL
Superficial MCL
Deep MCL
Medial meniscus
Iliotibial band (ITB)
ACL
Lateral meniscus


Posterior cruciate ligament (PCL)
Deep medial collateral ligament (MCL)
Medial meniscus
Superficial medial collateral ligament (MCL)
Anterior cruciate ligament (ACL)
Popliteus tendon
Lateral collateral ligament (LCL)
Lateral meniscus

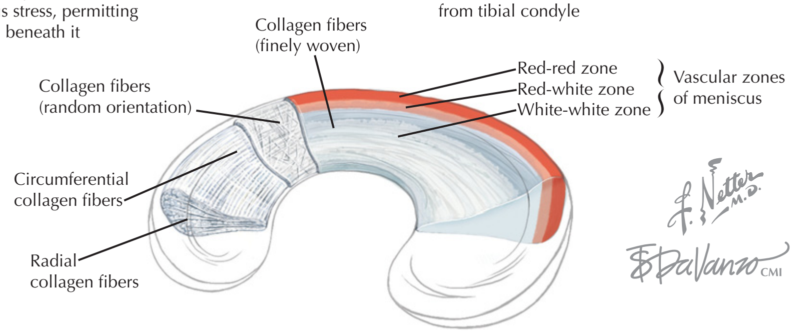
Ligaments of knee: coronal (frontal) section



Medial meniscus visualized below femoral condyle. Meniscus rises with valgus stress, permitting inspection beneath it



Lateral meniscus visualized. Varus stress raises meniscus from tibial condyle


Collagen fibers (finely woven)
Collagen fibers (random orientation)
Circumferential collagen fibers
Radial collagen fibers
Red-red zone
Red-white zone
White-white zone
Vascular zones of meniscus

MENISCUS

Structure

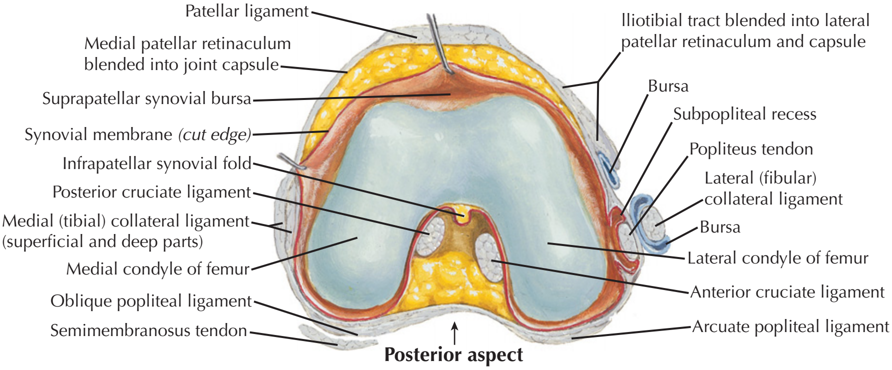
- Fibrocartilage discs interposed in femorotibial joints between femoral condyles and tibial plateaus. Have a triangular cross section—thickest at the periphery, then tapering to a thin central edge.
- Histologically made up of collagen (mostly type 1, also 2, 3, 5, 6), cells (fibrochondrocytes), water, proteoglycans, glycoproteins, elastin
- 3 layers seen microscopically:
  1. Superficial layer: woven collagen fiber pattern
  2. Surface layer: randomly oriented collagen fiber pattern
  3. Middle (deepest) layer: circumferential (longitudinal) oriented fibers. These fibers dissipate hoop stresses. Radial fibers. These fibers acts as "ties" to hold the circumferential fibers.
- Vascular supply from superior and inferior medial and lateral geniculate arteries. They form perimeniscal plexus in synovium/capsule. Peripheral portion (10-30% medially, 10-25% laterally) is vascular via vessels from the perimeniscal plexus. 3 zones:
  - Red zone: 3mm from capsular junction (most tears will heal)
  - Red/white zone: 3-5mm from capsular junction (some tears will heal)
  - White zone: >5mm from capsular junction (most tears will not heal)

  The central, avascular ⅔ of the menisci receive nutrition from the synovial fluid
- Medial meniscus: C-shaped, less mobile, firmly attached to tibia (via coronary ligaments) and capsule (via deep MCL) at midbody
- Lateral meniscus: "circular", more mobile, loose peripheral attachments, no attachment at popliteal hiatus (where popliteus tendon enters joint)

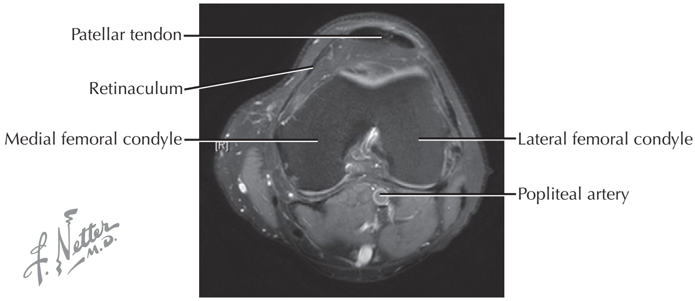
Function

1. **Load transmission and shock absorption:** the menisci absorb 50% (in extension) or 85% (in flexion) of forces across femorotibial joint. The transmission of this load to the meniscus helps protect the articular cartilage
2. **Joint congruity and stability:** the menisci create congruity between the curved condyles and flat plateaus, which increases stability. The menisci (esp. PHMM) also act as secondary stabilizers to translation (esp. in the ligament-deficient knee)
3. **Joint lubrication:** the menisci help distribute synovial fluid across the articular surfaces.
4. Joint nutrition: the menisci absorb, then release synovial fluid nutrients for the cartilage.
5. Proprioception: nerve endings provide sensory feedback for joint position.

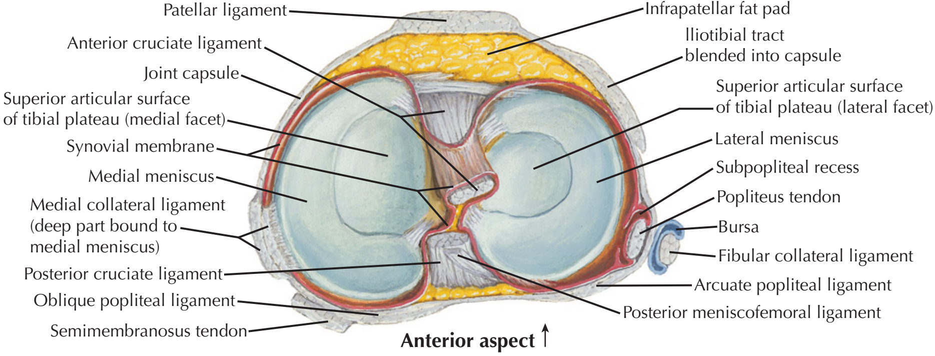
Inferior view


Patellar ligament
Medial patellar retinaculum blended into joint capsule
Suprapatellar synovial bursa
Synovial membrane *(cut edge)*
Infrapatellar synovial fold
Posterior cruciate ligament
Medial (tibial) collateral ligament (superficial and deep parts)
Medial condyle of femur
Oblique popliteal ligament
Semimembranosus tendon
Iliotibial tract blended into lateral patellar retinaculum and capsule
Bursa
Subpopliteal recess
Popliteus tendon
Lateral (fibular) collateral ligament
Bursa
Lateral condyle of femur
Anterior cruciate ligament
Arcuate popliteal ligament
↑
Posterior aspect

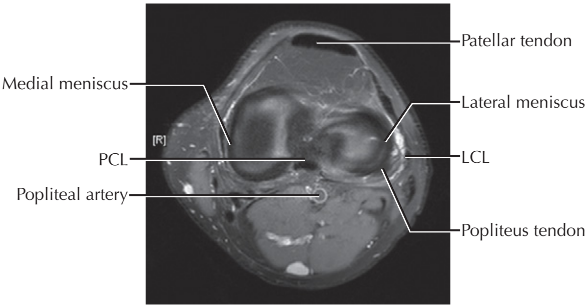
MRI


Patellar tendon
Retinaculum
Medial femoral condyle
[R]
Lateral femoral condyle
Popliteal artery
F. Netter M.D.

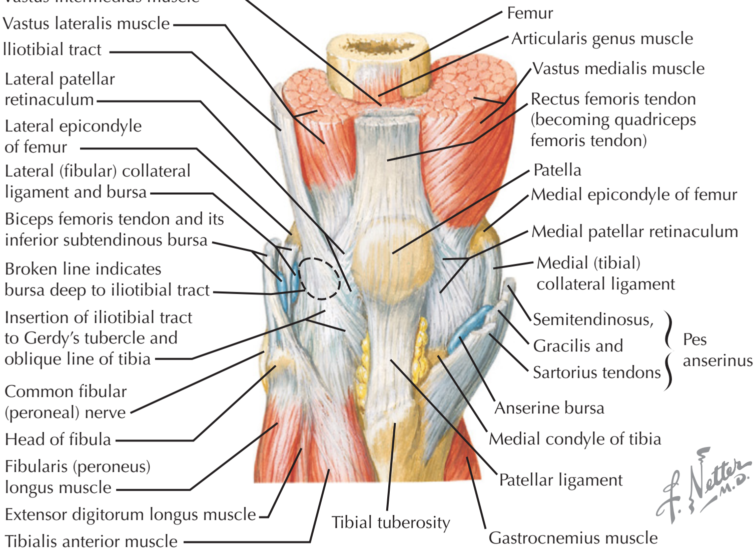
Superior view


Patellar ligament
Anterior cruciate ligament
Joint capsule
Superior articular surface of tibial plateau (medial facet)
Synovial membrane
Medial meniscus
Medial collateral ligament (deep part bound to medial meniscus)
Posterior cruciate ligament
Oblique popliteal ligament
Semimembranosus tendon
Infrapatellar fat pad
Iliotibial tract blended into capsule
Superior articular surface of tibial plateau (lateral facet)
Lateral meniscus
Subpopliteal recess
Popliteus tendon
Bursa
Fibular collateral ligament
Arcuate popliteal ligament
Posterior meniscofemoral ligament
Anterior aspect
↑

MRI

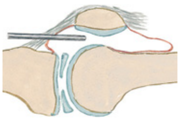

Medial meniscus
[R]
PCL
Popliteal artery
Patellar tendon
Lateral meniscus
LCL
Popliteus tendon

Right knee in extension


Vastus intermedius muscle
Vastus lateralis muscle
Iliotibial tract
Lateral patellar retinaculum
Lateral epicondyle of femur
Lateral (fibular) collateral ligament and bursa
Biceps femoris tendon and its inferior subtendinous bursa
Broken line indicates bursa deep to iliotibial tract
Insertion of iliotibial tract to Gerdy's tubercle and oblique line of tibia
Common fibular (peroneal) nerve
Head of fibula
Fibularis (peroneus) longus muscle
Extensor digitorum longus muscle
Tibialis anterior muscle
Tibial tuberosity
Femur
Articularis genus muscle
Vastus medialis muscle
Rectus femoris tendon (becoming quadriceps femoris tendon)
Patella
Medial epicondyle of femur
Medial patellar retinaculum
Medial (tibial) collateral ligament
Semitendinosus,
Gracilis and
Sartorius tendons
Pes anserinus
Anserine bursa
Medial condyle of tibia
Patellar ligament
Gastrocnemius muscle
F. Netter M.D.

Suprapatellar pouch

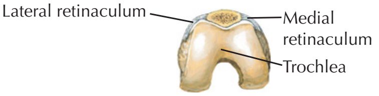
Arthroscopic view shows patella above, trochlear groove of femur below, suprapatellar pouch in between



Anteromedial compartment

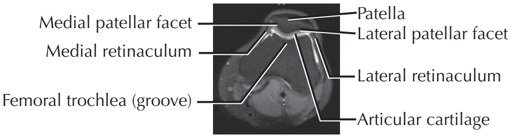
LIGAMENTS	ATTACHMENTS	FUNCTION/COMMENT
KNEE		
Patellofemoral Joint		
Function		
• Composed of quadriceps tendon, patella, patellar tendon (ligament), and additional patella-stabilizing ligaments. • Extensor mechanism (of the knee) is primary role of this joint. The patella increases the moment arm from joint axis, increasing the mechanical advantage and quadriceps pull in extension. • Stability of the patella in the trochlear groove results from both bony morphology and static and dynamic stabilizers. Hypoplastic LFC or patellar ridge, a flat trochlea, or increased "Q" angle can all predispose the patella to dislocation. • The patella begins to engage the trochlea at 20° of flexion and is fully engaged by 40°. The articulation point moves proximally with increased flexion. The odd facet (far medial) of the patella articulates in full flexion. • Joint reaction forces can be very high in this joint: 3× body weight with stairs, 7× body weight with deep bending. The articular cartilage is up to 5mm (thickest in the body) to accommodate for these high forces.		
Structure		
Quadriceps tendon	Quadriceps to superior pole of patella	Can rupture with eccentric contraction (usu. >40y.o.)
Patellar tendon (ligament)	Inferior pole of patella to tibial tuberosity	Can rupture with eccentric contraction (usu. >40y.o.)
Patellofemoral ligaments Medial (MPFL), lateral (LPFL)	Femoral epicondyles to medial/lateral patella	Primary stabilizers of patella (esp. MPFL)
Patellotibial ligaments (med. & lat.)	Tibial plateaus to medial/lateral patella	Minor patellar stabilizer
Patellomeniscal ligaments (med. & lat.)	Patella to periphery of menisci	Secondary stabilizers of patella
Patellar retinaculum (med. & lat.)	Inserts on both the femur and tibia	Minor patellar stabilizer
Other		
• Patella position can evaluated on lateral radiograph (30° flexion) with Insall ratio (patella [diagonal] length/patellar tendon length). Normal ratio is 1.0 (0.8 to 1.2). >1.2 indicates patella baja, <0.8 indicates patella alta. • Dynamic stabilizers: quadriceps, adductor magnus, ITB, and vastus medialis and lateralis • Medial patellofemoral ligament (MPFL): primary restraint to lateral dislocation (most common)		

Patellofemoral Joint

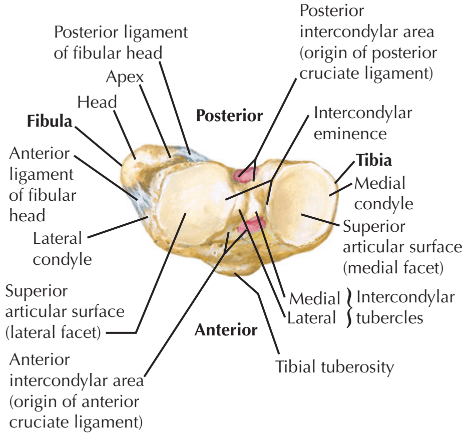

Lateral retinaculum
Medial retinaculum
Trochlea

Normally, patella rides in groove between medial and lateral femoral condyles

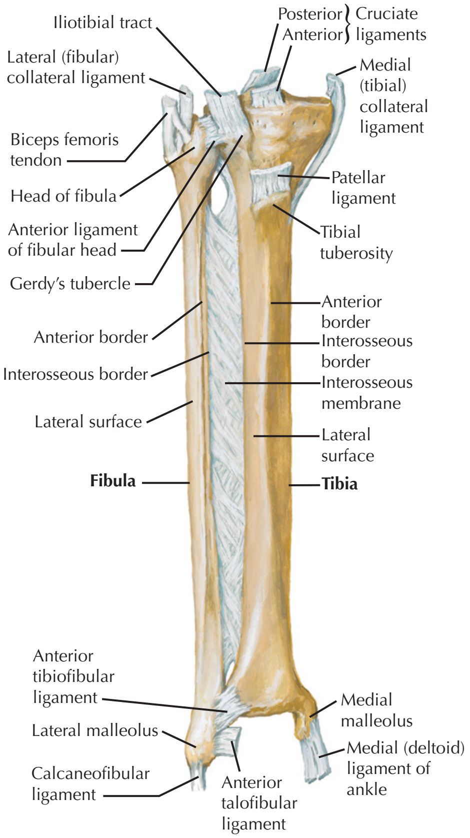
MRI


Medial patellar facet
Medial retinaculum
Femoral trochlea (groove)
Patella
Lateral patellar facet
Lateral retinaculum
Articular cartilage

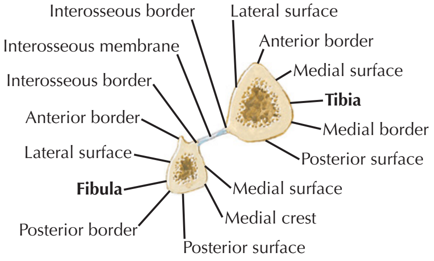
Superior view


Posterior ligament of fibular head
Apex
Head
Fibula
Anterior ligament of fibular head
Lateral condyle
Superior articular surface (lateral facet)
Anterior intercondylar area (origin of anterior cruciate ligament)
Posterior
Posterior intercondylar area (origin of posterior cruciate ligament)
Intercondylar eminence
Tibia
Medial condyle
Superior articular surface (medial facet)
Medial
Lateral
Intercondylar tubercles
Anterior
Tibial tuberosity

Anterior view with ligament attachments


Iliotibial tract
Lateral (fibular) collateral ligament
Biceps femoris tendon
Head of fibula
Anterior ligament of fibular head
Gerdy's tubercle
Anterior border
Interosseous border
Lateral surface
Fibula
Posterior
Anterior
Cruciate ligaments
Medial (tibial) collateral ligament
Patellar ligament
Tibial tuberosity
Anterior border
Interosseous border
Interosseous membrane
Lateral surface
Tibia
Anterior tibiofibular ligament
Lateral malleolus
Calcaneofibular ligament
Anterior talofibular ligament
Medial malleolus
Medial (deltoid) ligament of ankle

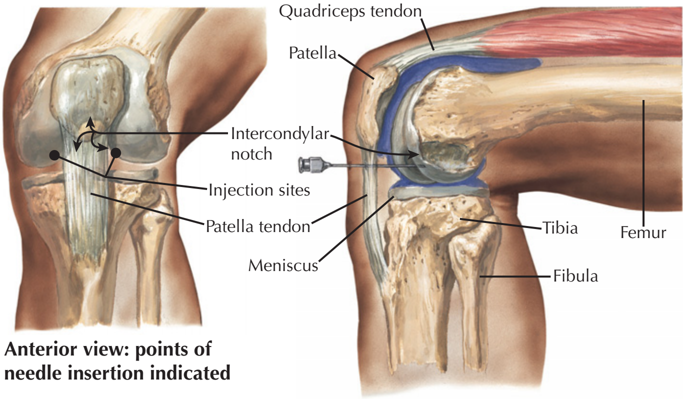
Cross section


Interosseous border
Interosseous membrane
Interosseous border
Anterior border
Lateral surface
Fibula
Posterior border
Lateral surface
Anterior border
Medial surface
Tibia
Medial border
Posterior surface
Medial surface
Medial crest
Posterior surface

LIGAMENTS	ATTACHMENTS	FUNCTION/COMMENT
PROXIMAL TIBIOFIBULAR JOINT		
Anterior tibiofibular ligament	Fibular head to anterior lateral tibia	Broader and stronger than posterior ligament
Posterior tibiofibular ligament	Fibular head to posterior lateral tibia	Weaker than anterior ligament
Other		
Interosseous membrane	Lateral tibia to medial fibula	Stout fibrous membrane separates anterior & posterior compartments. Is disrupted in Maisonneuve fracture

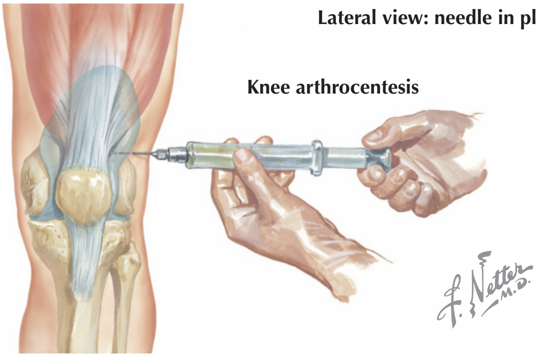
- This joint has minimal motion. Dislocation or disruption of this joint indicates high-energy trauma to the knee region.
- For distal tibiofibular joint, please see Chapter 10, Foot/Ankle.

Technique for injection of knee joint



Anterior view: points of needle insertion indicated

Lateral view: needle in place



Knee arthrocentesis

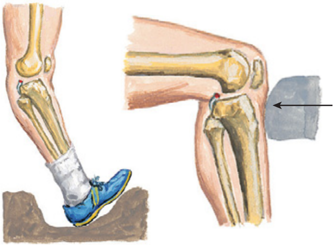
STEPS

INJECTION

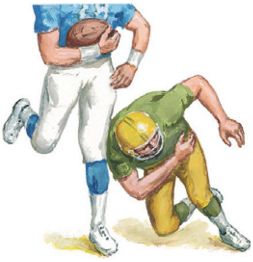
1. Ask patient about allergies.
2. Place patient in seated position with knee flexed and hanging.
3. Prep skin (iodine/soap) over the anterior knee.
4. Prepare syringe with local/steroid mixture on 21/22 gauge needle.
5. Palpate the "soft spot" between the border of the patellar tendon, the tibial plateau, and the femoral condyle.
6. May locally anesthetize the skin over the "soft spot."
7. Horizontally insert the needle into the "soft spot," aiming approximately 30° to the midline toward the intercondylar notch. If the needle hits the condyle, redirect it more centrally into the notch.
8. Gently aspirate to confirm that you are not in a vessel.
9. Inject solution into knee. The fluid should flow easily.
10. Withdraw needle and dress the injection site.

ASPIRATION/ARTHROCENTESIS

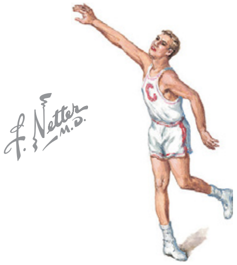
1. Ask patient about allergies.
2. Place patient supine with the knee fully extended.
3. Palpate the borders of the patella and femoral condyle.
4. Prep skin (iodine/antiseptic soap) over this area.
5. Insert needle, usually 21 or 18 gauge (for thick fluid), horizontally into suprapatellar pouch at level of superior pole of the patella.
6. Aspirate fluid into syringe (may use multiple syringes if needed).
7. Gently compress knee to "milk" fluid to the pouch for aspiration.
8. Withdraw needle and dress the injection site.



PCL Injury
Usual causes include hyperextension injury, as occurs from stepping into hole, and direct blow to flexed knee



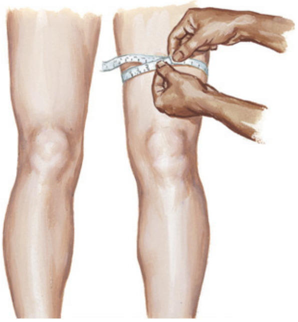
Sprains
Usual cause is forceful impact on posterolateral aspect of knee with foot anchored, producing valgus stress on knee joint

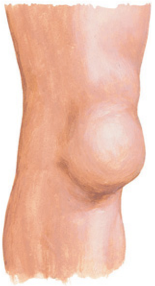


ACL Injury
Usual cause is twisting of hyperextended knee, as in landing after basketball jump shot

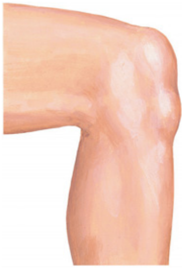
QUESTION	ANSWER	CLINICAL APPLICATION
1. Age	Young	Trauma: ligamentous or meniscal injury, fracture
	Middle aged, elderly	Arthritis
2. Pain		
a. Onset	Acute	Trauma: fx, dislocation, soft tissue (ligament/meniscus) injury, septic bursitis/arthritis
b. Location	Chronic	Arthritis, infection, tendinitis/bursitis, overuse, tumor
	Anterior	Quadriceps or patellar tear or tendinitis, prepatellar bursitis, patellofemoral dysfunction
	Posterior	Meniscus tear (posterior horn), Baker's cyst, PCL injury
	Lateral	Meniscus tear (joint line), collateral lig. injury, arthritis, ITB syndrome
		Meniscus tear (joint line), collateral ligament injury, arthritis, pes bursitis
	Medial	Tumor, infection
c. Occurrence	Night pain	Etiology of pain likely from joint
	With activity	
3. Stiffness	Without locking	Arthritis, effusion (trauma, infection)
	With locking/catching	Loose body, meniscal tear (esp. bucket handle), arthritis, synovial plica
4. Swelling	Intraarticular	Infection, trauma (OCD, meniscal tear, ACL/PCL injury, fracture)
	Extraarticular	Collateral ligament injury, bursitis, contusion, sprain
	Acute (post injury)	Acute (hours): ACL injury; subacute (day): meniscus injury, OCD
	Acute (without injury)	Infection: prepatellar bursitis, septic joint
5. Instability	Giving away/collapse	Cruciate or collateral ligament injury/extensor mechanism injury
	Giving away & pain	Patellar subluxation/dislocation, pathologic plica, OCD
6. Trauma	Mechanism: valgus	MCL injury (+/– terrible triad: MCL, ACL, medial meniscus injuries)
	Varus force	LCL or posterolateral corner injury
	Flexion/posterior	PCL injury (e.g., dashboard injury)
	Twisting	Noncontact: ACL injury; Contact: multiple ligaments
	Popping noise	Cruciate ligament injury (esp. ACL), osteochondral fx, meniscal tear
	None	Degenerative and overuse etiology
7. Activity	Agility/cutting sports	Cruciate (ACL #1) or collateral ligament
	Running, cycling etc.	Patellofemoral etiology
	Squatting	Meniscus tear
	Walking	Distance able to ambulate equates with severity of arthritic disease
8. Neurologic sx	Numbness, tingling	Neurologic disease, trauma (consider L-spine etiology)
9. Systemic	Fevers, chills	Infection, septic joint, tumor
10. Hx of arthritides	Multiple joints involved	Rheumatoid arthritis, gout, etc

Quadriceps atrophy

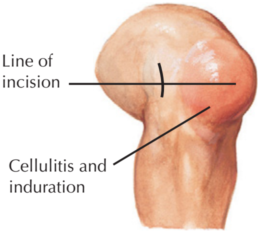




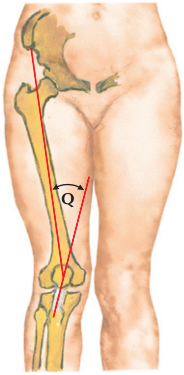
Prepatellar bursitis
(housemaid's knee)



Osgood-Schlatter Disease
Clinical appearance. Prominence over tibial tuberosity partly due to soft-tissue swelling and partly to avulsed fragments

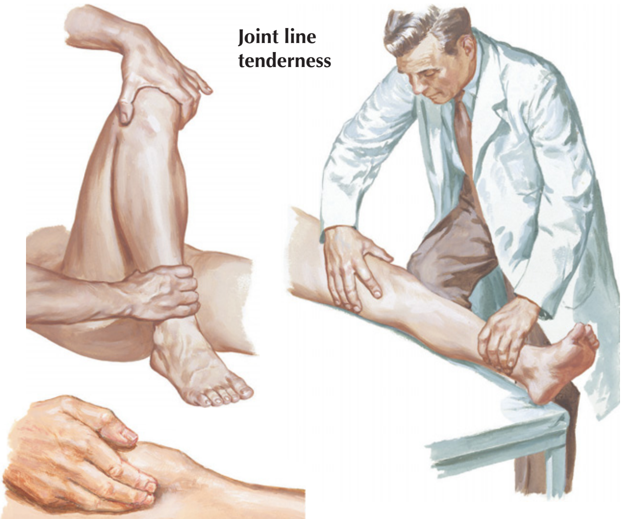


Incision and drainage often necessary

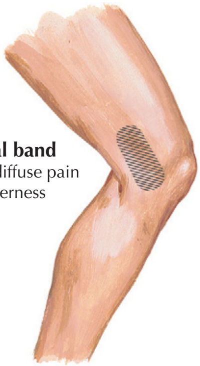


Q angle formed by intersection of lines from anterior superior iliac spine and from tibial tuberosity through midpoint of patella. Large Q angle predisposes to patellar subluxation.

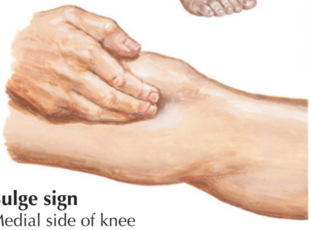
EXAM	TECHNIQUE/FINDINGS	CLINICAL APPLICATION/DDX
		INSPECTION
Gait	Varus thrust	Can indicate LCL or posterolateral corner injury/insufficiency
	Patella tracking	Maltracking can lead to patellofemoral symptoms
	Flexed knee gait	From tight Achilles tendon or hamstrings, can lead to patellofemoral symptoms
Anterior	Knee alignment	Normal knee alignment is clinically neutral (6° valgus radiographically). Evaluate while weight-bearing. Variations can be developmental or posttraumatic.
	Genu valgum (knock knee)	Can predispose to lateral compartment DJD, patella instability/maltracking
	Genu varum (bow leg)	Can predispose to medial compartment DJD, ligamentous incompetency
	Q angle	Angle from ASIS to mid-patella to tibial tubercle. Nl: male ≤10°, female ≤15°; increased angle predisposes to patellar subluxation, patellofemoral symptoms
	Swelling	Prepatellar: prepatellar bursitis (inflammatory or septic); intraarticular effusion: arthritis, infection, trauma (hemarthrosis): intraarticular fracture, meniscal tear, ligament rupture
	Enlarged tibial tubercle	May be result of Osgood-Schlatter disease (esp. in adolescents)
Posterior	Mass	Baker's cyst
Lateral	Knee alignment	Evaluated while weight-bearing
	Recurvatum	Possible PCL injury
	Patella position	Best evaluated radiographically with Insall ratio (see Joints, Patellofemoral)
	High-riding patella	Patella alta: can predispose to patella instability
	Low-riding patella	Patella baja: usually posttraumatic or postsurgical (possible arthrofibrosis)
Musculature	Quadriceps	Atrophy can result from injury, postoperative, or neurologic conditions
	Vastus medialis	VMO atrophy may contribute to patellofemoral symptoms



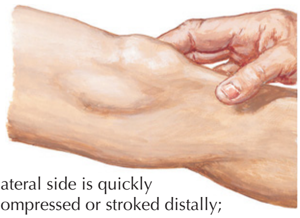
Joint line tenderness



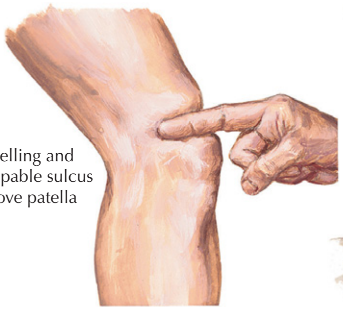
Iliotibial band
Area of diffuse pain and tenderness



Bulge sign
Medial side of knee compressed or stroked proximally to move fluid away from medial compartment.

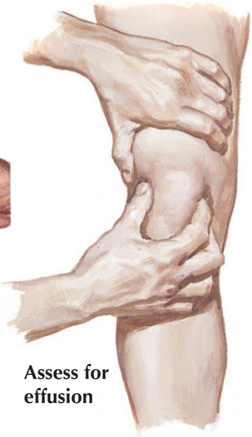


Lateral side is quickly compressed or stroked distally; bulge appears medial to patella.



Swelling and palpable sulcus above patella

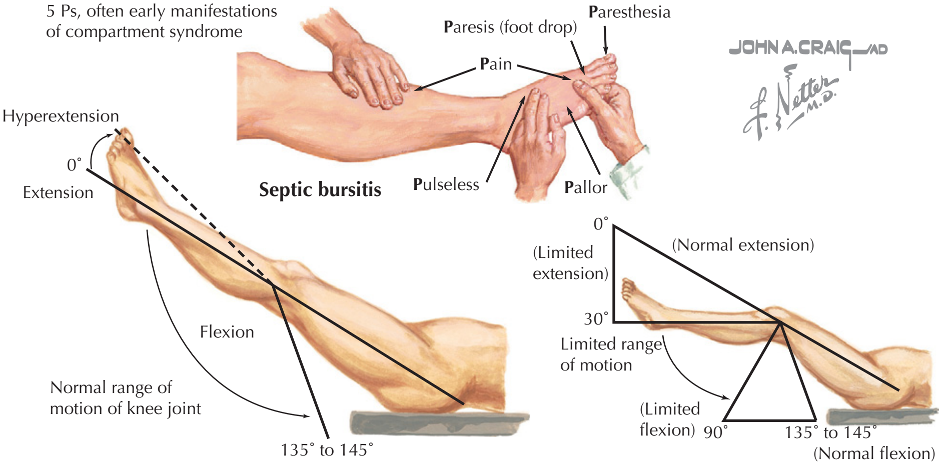
Rupture of quadriceps femoris tendon at superior margin of patella



Assess for effusion

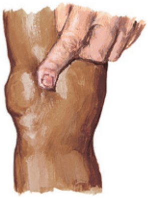
EXAM	TECHNIQUE/FINDINGS	CLINICAL APPLICATION/DDX
PALPATION		
Bony structures	Patella Tibial tubercle	Tenderness at distal pole: tendinitis (jumper's knee) Tenderness with Osgood-Schlatter disease
Soft tissues	Quadriceps tendon Patellar tendon Compress suprapatellar pouch Prepatellar bursa Pes anserine bursa Retinaculum/plica Medial joint line and MCL Lateral joint line and LCL Iliotibial band/LFC (anterolateral knee) Popliteal fossa Compartments of leg (anterior, posterior, lateral)	Defect: tendon rupture; tenderness: tendinitis Defect: tendon rupture; tenderness (esp. at insertion): tendinitis (jumper's knee) Ballotable patella (effusion): arthritis, trauma, infection Edematous/tender bursae indicate correlating bursitis Tenderness indicates bursitis Thickened, tender plica is pathologic Tenderness: medial meniscus tear or MCL injury Tenderness: lateral meniscus tear or LCL injury Pain or tightness is pathologic Mass consistent with Baker's cyst, popliteal aneurysm Firm or tense compartment: compartment syndrome

Acute Anterior Compartment Syndrome

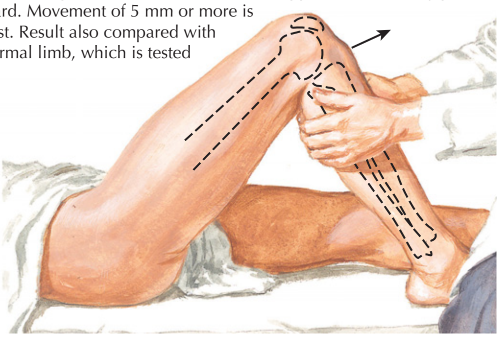

5 Ps, often early manifestations of compartment syndrome
Paresis (foot drop)
Paresthesia
Pain
Pulseless
Pallor
Septic bursitis
JOHN A.CRAIG_AD
F. Netter M.D.
Hyperextension
0°
Extension
Flexion
Normal range of motion of knee joint
135° to 145°
0°
(Limited extension)
(Normal extension)
30°
Limited range of motion
(Limited flexion) 90°
135° to 145°
(Normal flexion)

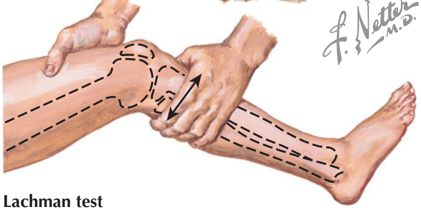
EXAM	TECHNIQUE/FINDINGS	CLINICAL APPLICATION/DDX
	RANGE OF MOTION	
Flexion/extension	Supine: heel to buttocks, then straight Note patellar tracking, pain, and crepitus	Normal: flex 0 to 125-135°, extend 0 to 5-15° Flexion contracture: common in OA/DJD Extensor lag (final 20º difficult): weak quadriceps Decreased extension with effusion Abnormal tracking leads to anterior knee pain
Tibial IR & ER	Stabilize femur, rotate tibia	Normal 10-15° IR/ER
	NEUROVASCULAR	
	Sensory	
Femoral nerve/saphenous (L4)	Medial leg	Deficit indicates corresponding nerve/root lesion
Peroneal nerve (L5) Lateral sural Superficial branch	 Proximal lateral leg Distal lateral leg	Deficit indicates corresponding nerve/root lesion
Tibial nerve (S1) Medial sural	 Proximal posterolateral leg	Deficit indicates corresponding nerve/root lesion
Sural nerve	Distal posterolateral leg	Deficit indicates corresponding nerve/root lesion
	Motor	
Femoral nerve (L2-4)	Knee extension	Weakness = Quadriceps or nerve/root lesion
Sciatic: Tibial (L4-S3) Peroneal (L4-S3)	Knee flexion Knee flexion	Weakness = Biceps (LH) or nerve/root lesion Weakness = Biceps (SH) or nerve/root lesion
Tibial nerve (S1)	Foot plantarflexion	Weakness = TP, FHL, FDL, or nerve/root lesion
Peroneal (deep) n. (L4) Peroneal (superficial) n. (L5)	Foot dorsiflexion Hallux dorsiflexion	Weakness = TA or nerve/root lesion Weakness = EHL or nerve/root lesion
	Other	
Reflex (L4)	Patellar	Hypoactive/absence indicates L4 radiculopathy Hyperactive may indicate UMN/myelopathic condition
Pulse	Popliteal	Diminished pulse can result from trauma

Apprehension (Fairbank) test As examiner displaces patella laterally, patient feels pain and forcefully contracts quadriceps femoris muscle.



Anterior drawer test
Patient supine on table, hip flexed 45°, knee 90°. Examiner sits on patient's foot to stabilize it, places hands on each side of upper calf and firmly pulls tibia forward. Movement of 5 mm or more is positive test. Result also compared with that for normal limb, which is tested first.

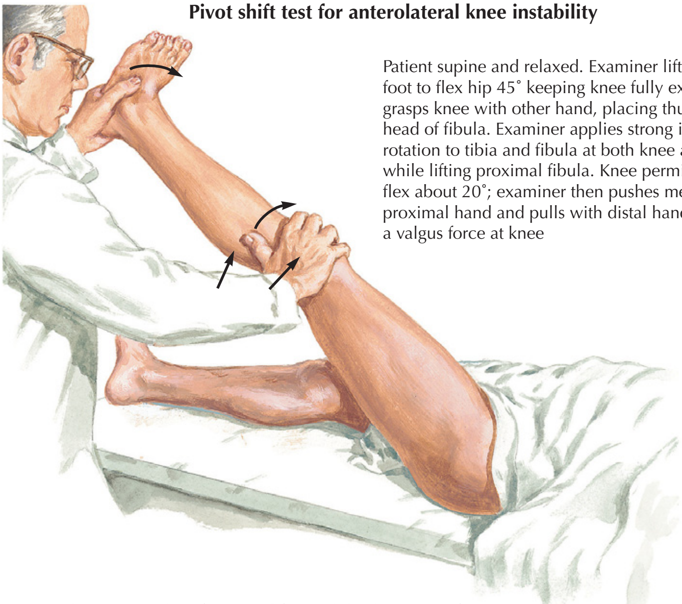




Lachman test
With patient's knee bent 20°–30°, examiner's hands grasp limb over distal femur and proximal tibia. Tibia pulled forward with femur stabilized. Movement of 5 mm or more than that in normal limb indicates rupture of anterior cruciate ligament.

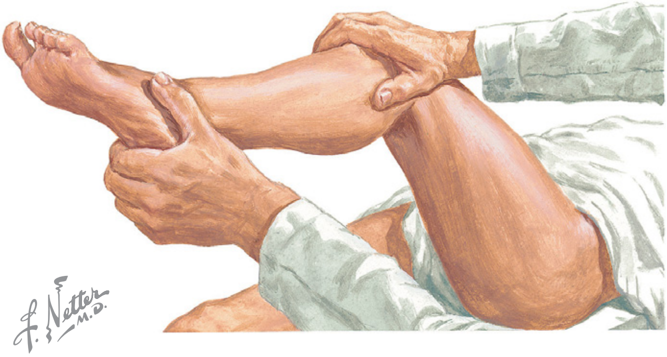
EXAM	TECHNIQUE	CLINICAL APPLICATION/DDX
	SPECIAL TESTS	
	Patellofemoral Joint	
Patella displacement	Translate patella medially & laterally	Divide patella into 4 quadrants. Patella should translate 2 quadrants in both directions. Decreased mobility indicates a tight retinaculum.
Patella apprehension	Relax knee, push patella laterally	Pain/apprehension of subluxation: patellar instability or medial retinaculum/MPFL injury
J sign	Actively extend knee from flexed position	Lateral displacement of patella in full extension: maltracking
Patella compression/grind	Extend knee, fire quads, compress patella	Pain: chondromalacia, OCD, PF arthritis/DJD of patella
	Meniscus	
Joint line tenderness	Palpate both joint lines	Most sensitive exam for meniscal tear when tender (see page 309)
McMurray	Flex/varus/ER knee, then extend Flex/valgus/IR knee, then extend	Pop or pain suggests medial, meniscal tear Pop or pain suggests lateral, meniscal tear
Apley's compression	Prone, knee 90°, compress & rotate	Pain or pop indicates meniscal tear
	Anterior Cruciate Ligament	
Lachman	Flex knee 20-30°, anterior force on tibia	Laxity indicates ACL injury. Most sensitive exam for ACL rupture. Grade 1: 0-5mm, 2: 6-10mm, 3: >10mm; A: good, B: no endpoint
Anterior drawer	Flex knee 90°, anterior force on tibia	Laxity/anterior translation: ACL injury
Pivot shift	Supine, extend knee, IR, valgus force on proximal tibia, then flex knee	Clunk with knee flexion indicates ACL injury. (If ACL is deficient, the tibia starts subluxated and reduces with flexion, causing the clunk.)

Pivot shift test for anterolateral knee instability

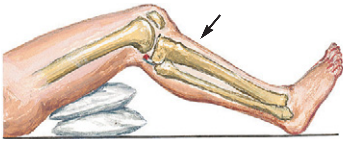


Patient supine and relaxed. Examiner lifts heel of foot to flex hip 45° keeping knee fully extended; grasps knee with other hand, placing thumb beneath head of fibula. Examiner applies strong internal rotation to tibia and fibula at both knee and ankle while lifting proximal fibula. Knee permitted to flex about 20°; examiner then pushes medially with proximal hand and pulls with distal hand to produce a valgus force at knee

As internal rotation, valgus force, and forward displacement of lateral tibial condyle maintained, knee passively flexed. If anterior subluxation of tibia (anterolateral instability) present, sudden visible, audible, and palpable reduction occurs at about 20°–40° flexion. Test positive if anterior cruciate ligament ruptured, especially if lateral capsular ligament also torn

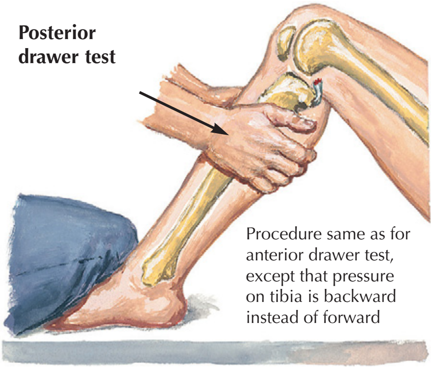


Posterior sag sign

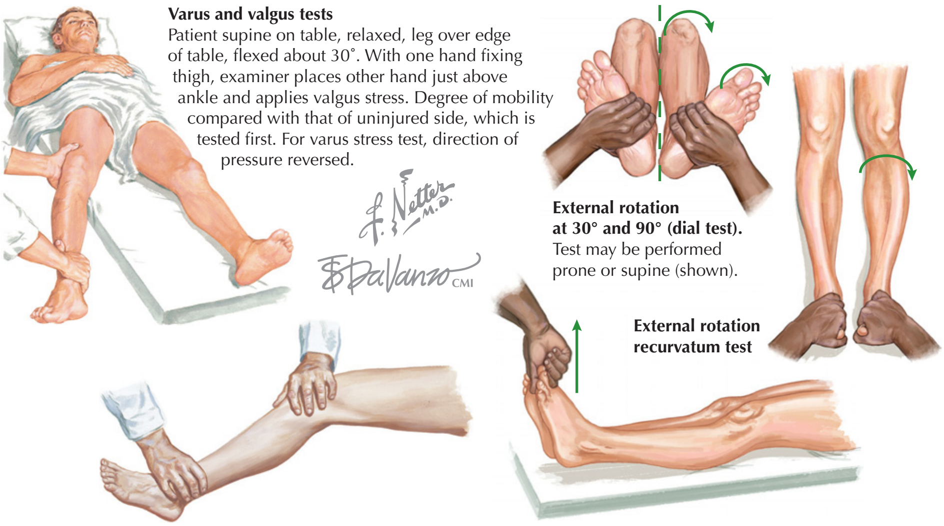


Leg drops backward

Posterior drawer test



Procedure same as for anterior drawer test, except that pressure on tibia is backward instead of forward

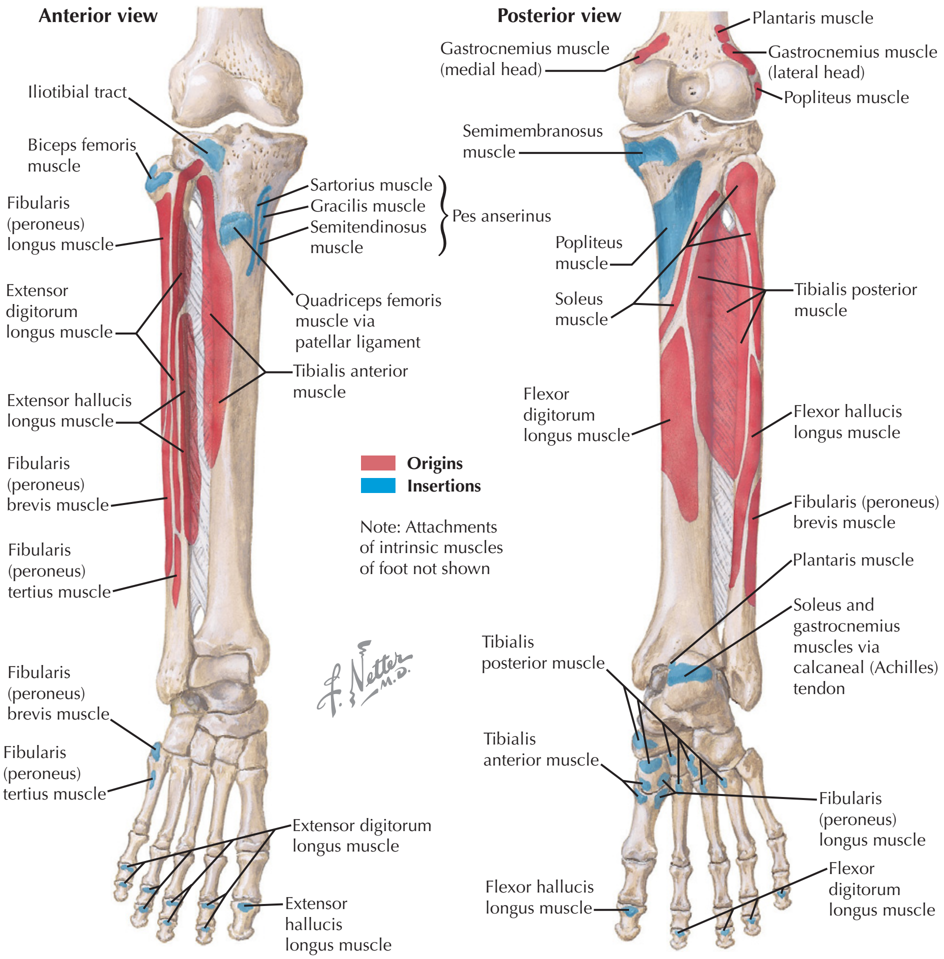


Varus and valgus tests
Patient supine on table, relaxed, leg over edge of table, flexed about 30˚. With one hand fixing thigh, examiner places other hand just above ankle and applies valgus stress. Degree of mobility compared with that of uninjured side, which is tested first. For varus stress test, direction of pressure reversed.

External rotation at 30° and 90° (dial test). Test may be performed prone or supine (shown).

External rotation recurvatum test

EXAM	TECHNIQUE	CLINICAL APPLICATION/DDX
SPECIAL TESTS		
Posterior Cruciate Ligament		
Posterior drawer	Flex knee 90°, posterior force on tibia	Posterior translation: PCL injury
Posterior sag	Supine, hip 45°, knee 90°, view laterally	Posterior translation of tibia (by gravity) on femur indicates PCL injury
Quadriceps active	Supine, knee 90°, fire quadriceps	Posteriorly subluxated tibia translates anteriorly if PCL is deficient
Reverse pivot shift	Supine, flex knee 45°, ER, valgus force on proximal tibia, then extend knee	Clunk with knee extension indicates PCL injury. (If PCL is deficient, the tibia is subluxated posteriorly, then reduces w/extension, causing the clunk.)
Collateral Ligaments		
Valgus stress	Lateral force to knee at 30°, then 0°	Laxity at 30°—MCL injury; 0°—MCL and cruciate ligament injury
Varus stress	Medial force to knee at 30°, then 0°	Laxity at 30°— LCL injury; 0°—LCL and cruciate ligament injury
Other		
Prone ER at 30° & 90° (Dial)	Prone, ER both knees at 90°, then 30° (can be done supine)	Increased ER at 30°: posterolateral corner (PLC) injury; at 90° PLC & PCL injuries
ER recurvatum	Supine, legs straight, raise legs by toes	Recurvatum, varus, and IR of knee indicates PLC (+/– PCL) injury
Slocum	Knee 90°, IR tibia 30°, anterior force Knee 90°, ER tibia 30°, anterior force	Displacement: anterior & lateral injury (ACL & PLC)) Displacement: anterior & medial inj. (ACL, MCL, POL)
Posterior lateral drawer	Knee 90º, ER tibia 15°, posterior force	Laxity indicates posterolateral corner and/or PCL injury
Posterior medial drawer	Knee 90°, IR tibia 30°, posterior force	Laxity indicates PCL and medial ligament (MCL, POL) injury


Anterior view
Iliotibial tract
Biceps femoris muscle
Fibularis (peroneus) longus muscle
Extensor digitorum longus muscle
Extensor hallucis longus muscle
Fibularis (peroneus) brevis muscle
Fibularis (peroneus) tertius muscle
Fibularis (peroneus) brevis muscle
Fibularis (peroneus) tertius muscle
Sartorius muscle
Gracilis muscle
Semitendinosus muscle
Pes anserinus
Quadriceps femoris muscle via patellar ligament
Tibialis anterior muscle
Extensor digitorum longus muscle
Extensor hallucis longus muscle
🟥 Origins
🟦 Insertions
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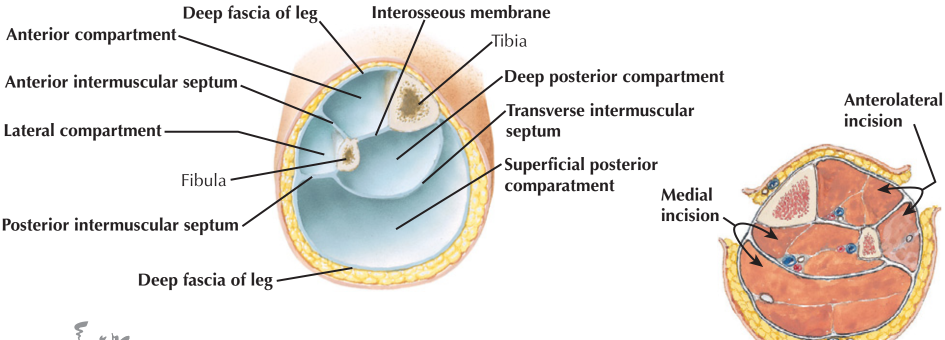
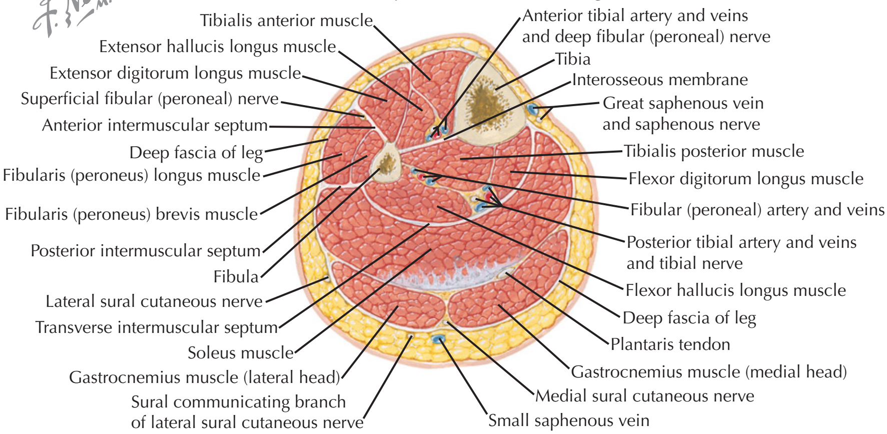
Posterior view
Gastrocnemius muscle (medial head)
Plantaris muscle
Gastrocnemius muscle (lateral head)
Popliteus muscle
Semimembranosus muscle
Popliteus muscle
Soleus muscle
Tibialis posterior muscle
Flexor digitorum longus muscle
Flexor hallucis longus muscle
Fibularis (peroneus) brevis muscle
Plantaris muscle
Soleus and gastrocnemius muscles via calcaneal (Achilles) tendon
Tibialis posterior muscle
Tibialis anterior muscle
Fibularis (peroneus) longus muscle
Flexor hallucis longus muscle
Flexor digitorum longus muscle

Note: Attachments of intrinsic muscles of foot not shown

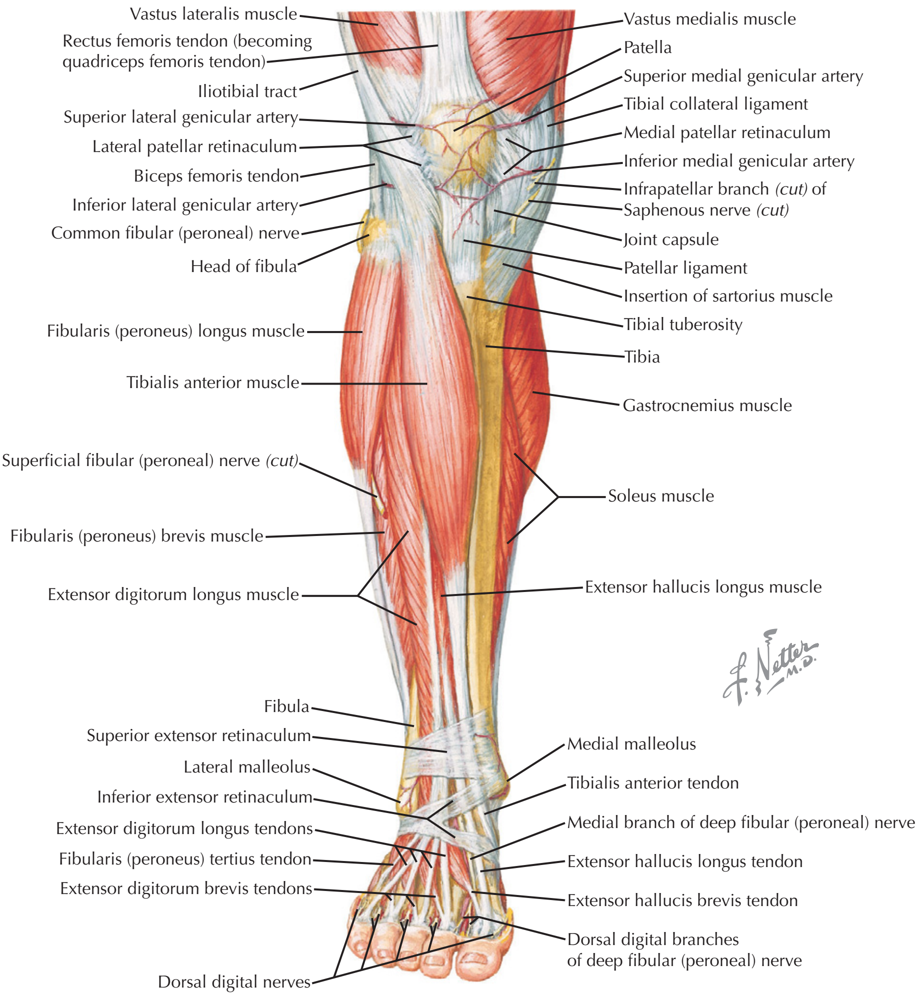
LATERAL FEMORAL CONDYLE	MEDIAL FEMORAL CONDYLE	FIBULAR HEAD	PROXIMAL TIBIA
ORIGINS			
Lateral gastrocnemius Plantaris Popliteus (ant. & inf. to LCL) **Ligaments:** Lateral collateral lig. (LCL)	Medial gastrocnemius	Soleus	Tibialis anterior (Gerdy's tub.) Extensor digitorum longus
INSERTIONS			
	Adductor magnus (adductor tub.) **Ligaments:** Medial collateral lig. (MCL)	Biceps femoris **Ligaments:** Lateral collateral lig. (LCL) Popliteofibular ligament Arcuate ligament Fabellofibular ligament	Quadriceps (tibial tubercle) Iliotibial band (Gerdy's tub.) Pes tendons (sar, grac, semi) Semimembranosus (postmed.) Popliteus (posteriorly) **Ligaments**: Medial collateral lig. (MCL)


Deep fascia of leg
Interosseous membrane
Anterior compartment
Tibia
Anterior intermuscular septum
Deep posterior compartment
Transverse intermuscular septum
Lateral compartment
Fibula
Superficial posterior comparatment
Posterior intermuscular septum
Deep fascia of leg
Anterolateral incision
Medial incision

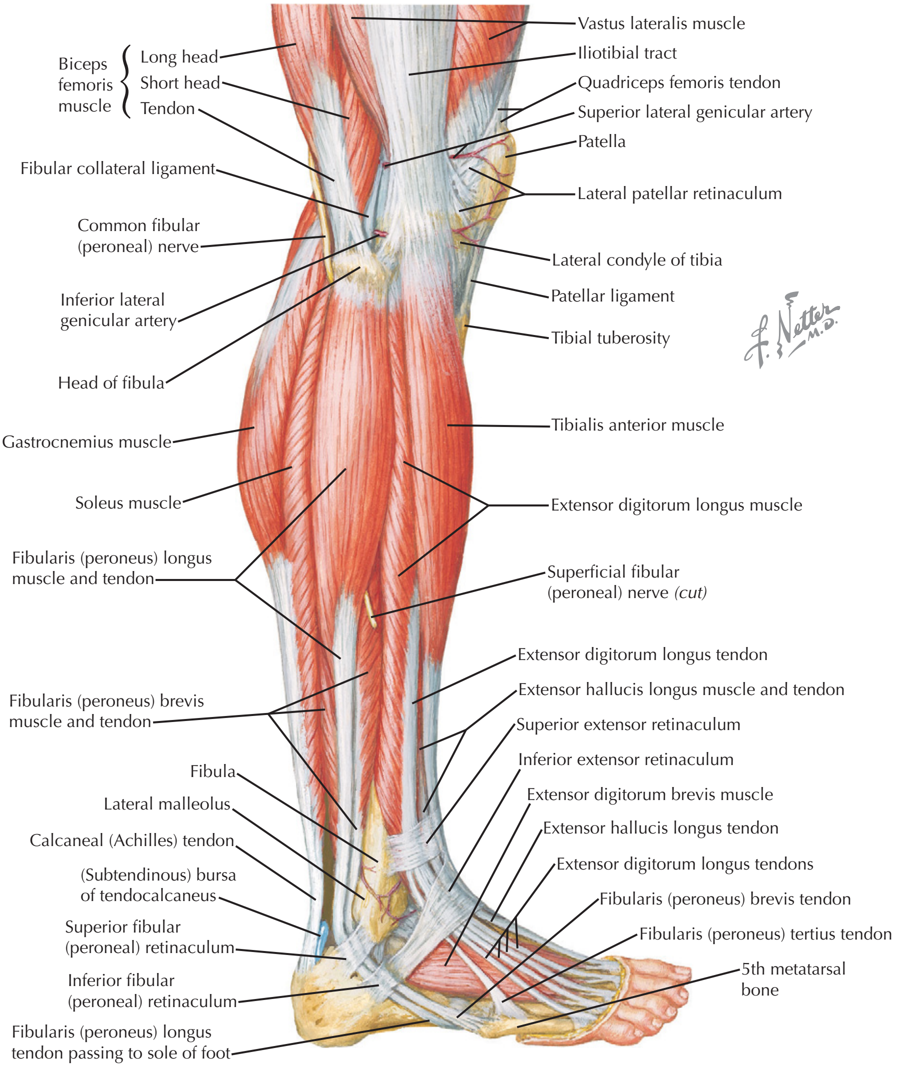
Cross section just above middle of leg


Tibialis anterior muscle
Extensor hallucis longus muscle
Extensor digitorum longus muscle
Superficial fibular (peroneal) nerve
Anterior intermuscular septum
Deep fascia of leg
Fibularis (peroneus) longus muscle
Fibularis (peroneus) brevis muscle
Posterior intermuscular septum
Fibula
Lateral sural cutaneous nerve
Transverse intermuscular septum
Soleus muscle
Gastrocnemius muscle (lateral head)
Sural communicating branch of lateral sural cutaneous nerve
Anterior tibial artery and veins and deep fibular (peroneal) nerve
Tibia
Interosseous membrane
Great saphenous vein and saphenous nerve
Tibialis posterior muscle
Flexor digitorum longus muscle
Fibular (peroneal) artery and veins
Posterior tibial artery and veins and tibial nerve
Flexor hallucis longus muscle
Deep fascia of leg
Plantaris tendon
Gastrocnemius muscle (medial head)
Medial sural cutaneous nerve
Small saphenous vein

COMPARTMENT	MUSCLES	NEUROVASCULAR STRUCTURE
	COMPARTMENTS (4)	
Anterior	Tibialis anterior (TA) Extensor hallucis longus (EHL) Extensor digitorum longus (EDL) Peroneus tertius	Deep peroneal nerve Anterior tibial artery and vein
Lateral	Peroneus longus Peroneus brevis	Superficial peroneal nerve
Superficial posterior	Gastrocnemius Soleus Plantaris	None
Deep posterior	Posterior tibialis (PT) Flexor hallucis longus (FHL) Flexor digitorum longus (FDL) Popliteus	Tibial nerve Posterior tibial artery and vein Peroneal artery and vein
	FASCIOTOMIES	
Anterolateral	Centered over the intermuscular septum between the anterior and lateral compartments	
Medial	Centered over the posterior tibial border/septum between the superficial and deep posterior compartments	


Vastus lateralis muscle
Rectus femoris tendon (becoming quadriceps femoris tendon)
Iliotibial tract
Superior lateral genicular artery
Lateral patellar retinaculum
Biceps femoris tendon
Inferior lateral genicular artery
Common fibular (peroneal) nerve
Head of fibula
Fibularis (peroneus) longus muscle
Tibialis anterior muscle
Superficial fibular (peroneal) nerve *(cut)*
Fibularis (peroneus) brevis muscle
Extensor digitorum longus muscle
Fibula
Superior extensor retinaculum
Lateral malleolus
Inferior extensor retinaculum
Extensor digitorum longus tendons
Fibularis (peroneus) tertius tendon
Extensor digitorum brevis tendons
Dorsal digital nerves
Vastus medialis muscle
Patella
Superior medial genicular artery
Tibial collateral ligament
Medial patellar retinaculum
Inferior medial genicular artery
Infrapatellar branch *(cut)* of Saphenous nerve *(cut)*
Joint capsule
Patellar ligament
Insertion of sartorius muscle
Tibial tuberosity
Tibia
Gastrocnemius muscle
Soleus muscle
Extensor hallucis longus muscle
Medial malleolus
Tibialis anterior tendon
Medial branch of deep fibular (peroneal) nerve
Extensor hallucis longus tendon
Extensor hallucis brevis tendon
Dorsal digital branches of deep fibular (peroneal) nerve

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
ANTERIOR COMPARTMENT					
Tibialis anterior (TA)	Proximal lateral tibia, (Gerdy's tubercle)	Med. cuneiform, plantar 1st metatarsal base	Deep peroneal	Dorsiflex, invert foot	Test L4 motor function
Extensor hallucis longus (EHL)	Medial fibula, interosseous membrane	Base of distal phalanx of great toe	Deep peroneal	Dorsiflex, extend great toe	Test L5 motor function
Extensor digitorum longus (EDL)	Lateral tibia condyle & proximal fibula	Base of middle & distal phalanges (4 toes)	Deep peroneal	Dorsiflex, extend lateral 4 toes	Single tendon divides into four tendons
Peroneus tertius	Distal fibula, interosseous membrane	Base of 5th metatarsal	Deep peroneal	Dorsiflex, evert foot (weak)	Often adjoined to the EDL


Biceps femoris muscle
Long head
Short head
Tendon
Fibular collateral ligament
Common fibular (peroneal) nerve
Inferior lateral genicular artery
Head of fibula
Gastrocnemius muscle
Soleus muscle
Fibularis (peroneus) longus muscle and tendon
Fibularis (peroneus) brevis muscle and tendon
Fibula
Lateral malleolus
Calcaneal (Achilles) tendon
(Subtendinous) bursa of tendocalcaneus
Superior fibular (peroneal) retinaculum
Inferior fibular (peroneal) retinaculum
Fibularis (peroneus) longus tendon passing to sole of foot
Vastus lateralis muscle
Iliotibial tract
Quadriceps femoris tendon
Superior lateral genicular artery
Patella
Lateral patellar retinaculum
Lateral condyle of tibia
Patellar ligament
Tibial tuberosity
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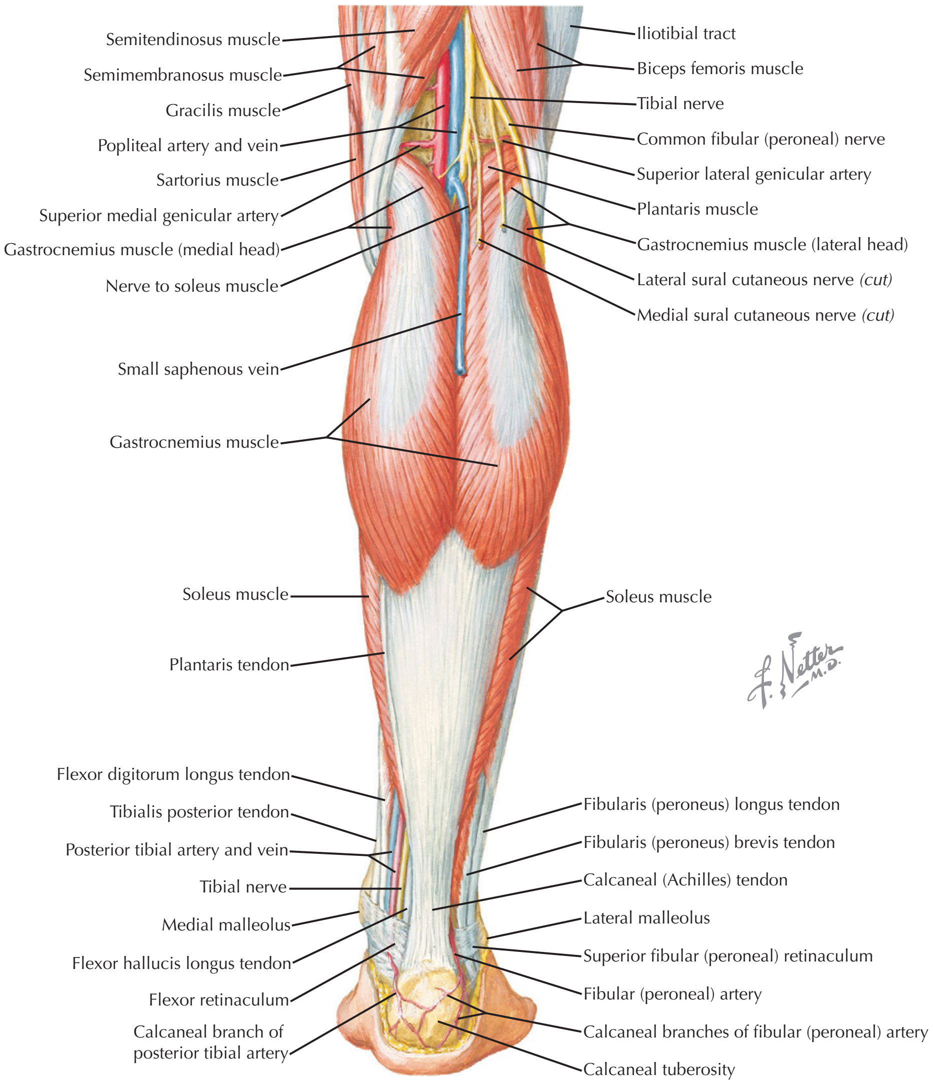
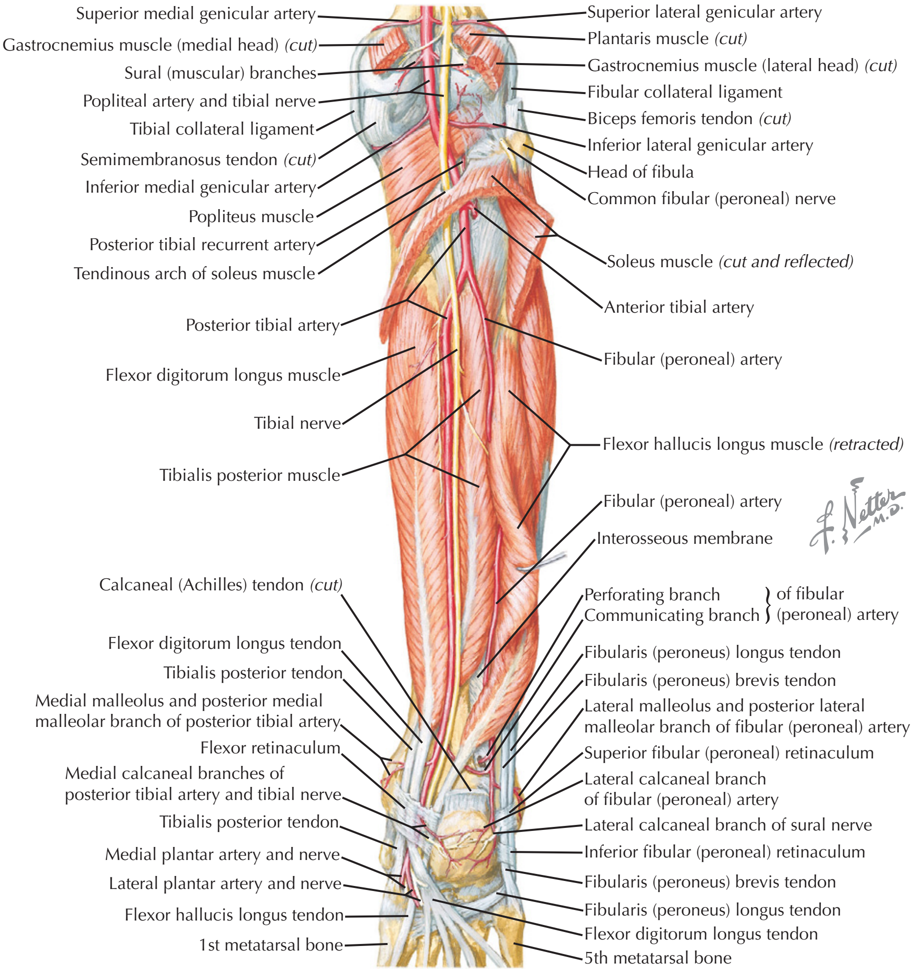
Tibialis anterior muscle
Extensor digitorum longus muscle
Superficial fibular (peroneal) nerve *(cut)*
Extensor digitorum longus tendon
Extensor hallucis longus muscle and tendon
Superior extensor retinaculum
Inferior extensor retinaculum
Extensor digitorum brevis muscle
Extensor hallucis longus tendon
Extensor digitorum longus tendons
Fibularis (peroneus) brevis tendon
Fibularis (peroneus) tertius tendon
5th metatarsal bone

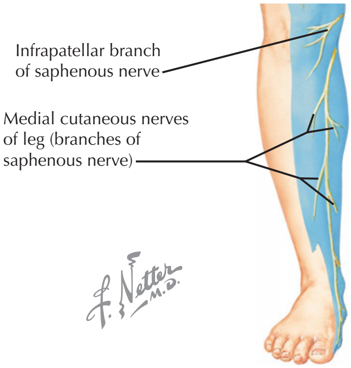
MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
LATERAL COMPARTMENT					
Peroneus longus	Proximal lateral fibula	Plantar medial cuneiform, 1st metatarsal base	Superficial peroneal	Plantar flex foot (1st ray)	Test S1 motor function; runs under the foot
Peroneus brevis	Distal lateral fibula	Base of 5th metatarsal	Superficial peroneal	Evert foot	Can cause avulsion fx at base of 5th MT; has most distal muscle belly


Semitendinosus muscle
Semimembranosus muscle
Gracilis muscle
Popliteal artery and vein
Sartorius muscle
Superior medial genicular artery
Gastrocnemius muscle (medial head)
Nerve to soleus muscle
Small saphenous vein
Gastrocnemius muscle
Soleus muscle
Plantaris tendon
Flexor digitorum longus tendon
Tibialis posterior tendon
Posterior tibial artery and vein
Tibial nerve
Medial malleolus
Flexor hallucis longus tendon
Flexor retinaculum
Calcaneal branch of posterior tibial artery
Iliotibial tract
Biceps femoris muscle
Tibial nerve
Common fibular (peroneal) nerve
Superior lateral genicular artery
Plantaris muscle
Gastrocnemius muscle (lateral head)
Lateral sural cutaneous nerve *(cut)*
Medial sural cutaneous nerve *(cut)*
Soleus muscle
Fibularis (peroneus) longus tendon
Fibularis (peroneus) brevis tendon
Calcaneal (Achilles) tendon
Lateral malleolus
Superior fibular (peroneal) retinaculum
Fibular (peroneal) artery
Calcaneal branches of fibular (peroneal) artery
Calcaneal tuberosity

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
SUPERFICIAL POSTERIOR COMPARTMENT					
Gastrocnemius	Lateral and medial femoral condyles	Calcaneus (via Achilles tendon)	Tibial	Plantar flex foot	Test S1 motor function; two heads, fabella is in tendon of lateral head
Soleus	Posterior fibular head/soleal line of tibia	Calcaneus (via Achilles tendon)	Tibial	Plantar flex foot	Fuses to gastrocnemius at Achilles tendon
Plantaris	Lateral femoral supracondylar line	Calcaneus	Tibial	Plantar flex foot (weak)	Long tendon can be harvested for tendon reconstruction


Superior medial genicular artery
Gastrocnemius muscle (medial head) *(cut)*
Sural (muscular) branches
Popliteal artery and tibial nerve
Tibial collateral ligament
Semimembranosus tendon *(cut)*
Inferior medial genicular artery
Popliteus muscle
Posterior tibial recurrent artery
Tendinous arch of soleus muscle
Posterior tibial artery
Flexor digitorum longus muscle
Tibial nerve
Tibialis posterior muscle
Calcaneal (Achilles) tendon *(cut)*
Flexor digitorum longus tendon
Tibialis posterior tendon
Medial malleolus and posterior medial malleolar branch of posterior tibial artery
Flexor retinaculum
Medial calcaneal branches of posterior tibial artery and tibial nerve
Tibialis posterior tendon
Medial plantar artery and nerve
Lateral plantar artery and nerve
Flexor hallucis longus tendon
1st metatarsal bone
Superior lateral genicular artery
Plantaris muscle *(cut)*
Gastrocnemius muscle (lateral head) *(cut)*
Fibular collateral ligament
Biceps femoris tendon *(cut)*
Inferior lateral genicular artery
Head of fibula
Common fibular (peroneal) nerve
Soleus muscle *(cut and reflected)*
Anterior tibial artery
Fibular (peroneal) artery
Flexor hallucis longus muscle *(retracted)*
Fibular (peroneal) artery
Interosseous membrane
Perforating branch } of fibular
Communicating branch } (peroneal) artery
Fibularis (peroneus) longus tendon
Fibularis (peroneus) brevis tendon
Lateral malleolus and posterior lateral malleolar branch of fibular (peroneal) artery
Superior fibular (peroneal) retinaculum
Lateral calcaneal branch of fibular (peroneal) artery
Lateral calcaneal branch of sural nerve
Inferior fibular (peroneal) retinaculum
Fibularis (peroneus) brevis tendon
Fibularis (peroneus) longus tendon
Flexor digitorum longus tendon
5th metatarsal bone

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
DEEP POSTERIOR COMPARTMENT					
Popliteus	Lateral femoral condyle (anterior and distal to LCL)	Proximal posterior tibia	Tibial	IR tibia/knee (during "swing" phase)	Origin is intraarticular; primary restraint to ER of knee
Flexor hallucis longus (FHL)	Posterior fibula	Base of distal phalanx of great toe	Tibial	Plantar flex great toe	Test S1 motor function
Flexor digitorum longus (FDL)	Posterior tibia	Bases of distal phalanges of 4 toes	Tibial	Plantar flex lateral 4 toes	At ankle, tendon is just anterior to tibial artery
Tibialis posterior (TP)	Posterior tibia, fibula, interosseous membrane	Plantar navicular cuneiforms, MT bases	Tibial	Plantar flex and invert foot (in "heel off" phase)	Tendon rupture/ degen. can cause acquired flat foot


Infrapatellar branch of saphenous nerve
Medial cutaneous nerves of leg (branches of saphenous nerve)
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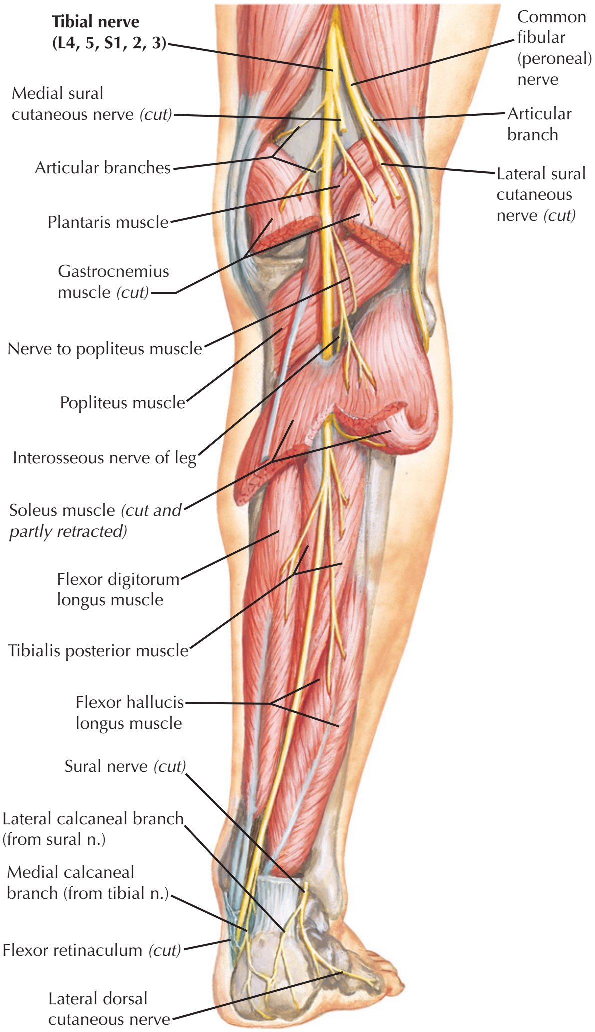
Tibial nerve


Tibial nerve (L4, 5, S1, 2, 3)
Common fibular (peroneal) nerve
Medial sural cutaneous nerve (cut)
Articular branch
Articular branches
Lateral sural cutaneous nerve (cut)
Plantaris muscle
Gastrocnemius muscle (cut)
Nerve to popliteus muscle
Popliteus muscle
Interosseous nerve of leg
Soleus muscle (cut and partly retracted)
Flexor digitorum longus muscle
Tibialis posterior muscle
Flexor hallucis longus muscle
Sural nerve (cut)
Lateral calcaneal branch (from sural n.)
Medial calcaneal branch (from tibial n.)
Flexor retinaculum (cut)
Lateral dorsal cutaneous nerve

LUMBAR PLEXUS

Posterior Division

***Saphenous* (L2-4):** Branch of femoral nerve, enters leg posteromedially, superficial to sartorial fascia (at risk in direct medial approach, e.g., MMR). It then gives off infrapatellar branch (at risk in anteromedial & midline approaches, e.g., ACLR), and descends in medial leg.

Sensory: Infrapatellar region: via **infrapatellar branch**
Medial leg: via **medial cutaneous** nerves
Motor: None (in leg)

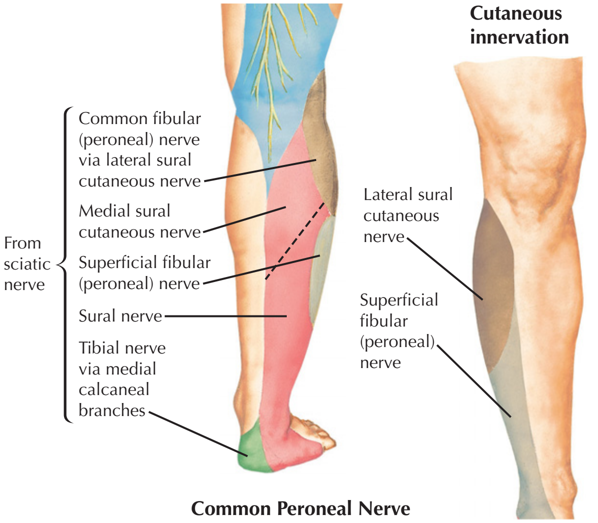
SACRAL PLEXUS

Anterior Division

***Tibial* (L4-S3):** descends b/w heads of gastrocnemius into leg, posterior to posterior tibialis muscle (in deep posterior compartment) to ankle just posterior to medial malleolus b/w FDL and FHL tendons.

Sensory: Proximal posterolateral leg: via **medial sural nerve**

Motor:
- Super. post. compartment
    - Plantaris
    - Gastrocnemius
    - Soleus: via **n. to soleus**
- Deep post. compartment
    - Popliteus: via **n. to popliteus**
    - Posterior tibialis (PT)
    - Flexor digitorum longus
    - Flexor hallucis longus


Cutaneous innervation
From sciatic nerve
Common fibular (peroneal) nerve via lateral sural cutaneous nerve
Medial sural cutaneous nerve
Superficial fibular (peroneal) nerve
Sural nerve
Tibial nerve via medial calcaneal branches
Lateral sural cutaneous nerve
Superficial fibular (peroneal) nerve

SACRAL PLEXUS

Posterior Division

Common peroneal (L4-S2): divides from sciatic nerve in distal posterior thigh, runs posteroinferior to biceps femoris, around fibular neck (can be compressed or injured), then divides into 2 branches.

Sensory: Proximal lateral leg: via **lateral sural nerve**
Motor: None (before dividing)

Deep peroneal: runs in anterior compartment of leg with anterior tibial artery, posterior to tibialis anterior on interosseous membrane.

Sensory: None (in leg)
Motor:
- Anterior compartment
  - Tibialis anterior (TA)
  - Extensor hallucis longus
  - Ext. digitorum longus
  - Peroneus tertius

Superficial peroneal: Runs in lateral compartment of leg, crosses anteriorly 12cm above lateral malleolus (injured in lateral ankle approach, e.g., ankle ORIF) to dorsal foot, then divides into 2 branches.

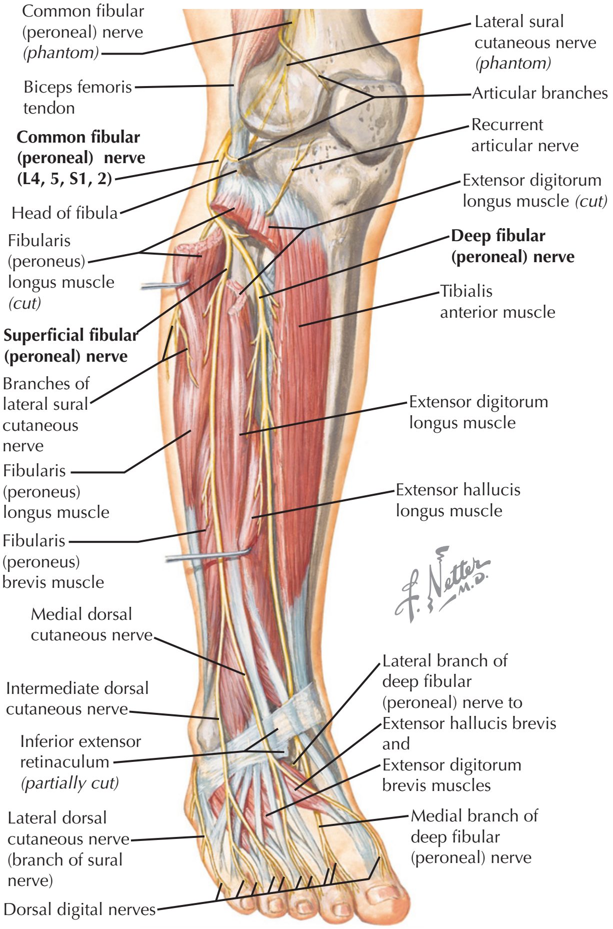
Sensory: Anterolateral leg
Motor:
- Lateral compartment
  - Peroneus longus (PL)
  - Peroneus brevis (PB)

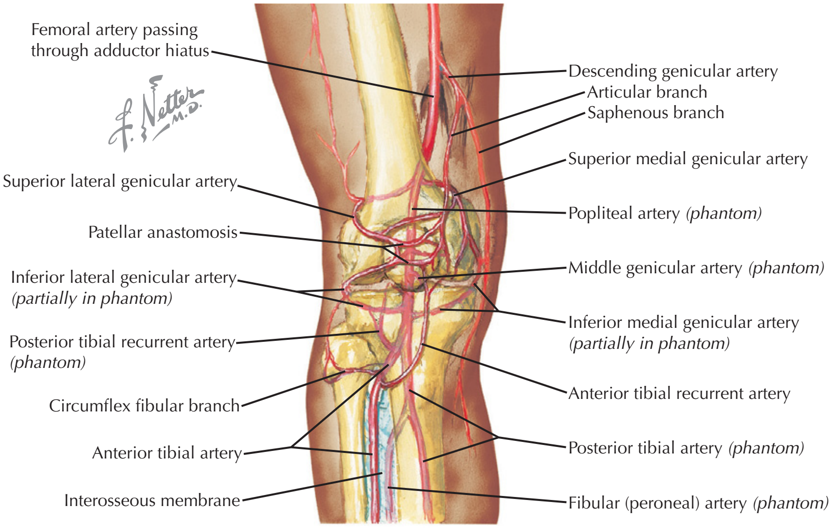
Other

Sural: Formed from **medial sural** cutaneous (tibial nerve) & **lateral sural** cutaneous (peroneal nerve), runs subcutaneously in posterolateral leg, crosses Achilles tendon 10cm above insertion, then to lateral heel.

Sensory: Posterolateral distal leg
Motor: None

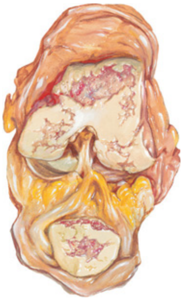
Common Peroneal Nerve


Common fibular (peroneal) nerve (phantom)
Biceps femoris tendon
Common fibular (peroneal) nerve (L4, 5, S1, 2)
Head of fibula
Fibularis (peroneus) longus muscle (cut)
Superficial fibular (peroneal) nerve
Branches of lateral sural cutaneous nerve
Fibularis (peroneus) longus muscle
Fibularis (peroneus) brevis muscle
Medial dorsal cutaneous nerve
Intermediate dorsal cutaneous nerve
Inferior extensor retinaculum (partially cut)
Lateral dorsal cutaneous nerve (branch of sural nerve)
Dorsal digital nerves
Lateral sural cutaneous nerve (phantom)
Articular branches
Recurrent articular nerve
Extensor digitorum longus muscle (cut)
Deep fibular (peroneal) nerve
Tibialis anterior muscle
Extensor digitorum longus muscle
Extensor hallucis longus muscle
F. Netter M.D.
Lateral branch of deep fibular (peroneal) nerve to Extensor hallucis brevis and Extensor digitorum brevis muscles
Medial branch of deep fibular (peroneal) nerve


Femoral artery passing through adductor hiatus
Superior lateral genicular artery
Patellar anastomosis
Inferior lateral genicular artery *(partially in phantom)*
Posterior tibial recurrent artery *(phantom)*
Circumflex fibular branch
Anterior tibial artery
Interosseous membrane
Descending genicular artery
Articular branch
Saphenous branch
Superior medial genicular artery
Popliteal artery *(phantom)*
Middle genicular artery *(phantom)*
Inferior medial genicular artery *(partially in phantom)*
Anterior tibial recurrent artery
Posterior tibial artery *(phantom)*
Fibular (peroneal) artery *(phantom)*

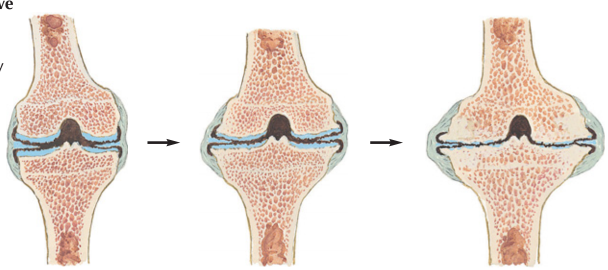
COURSE	BRANCHES	COMMENT/SUPPLY
POPLITEAL ARTERY		
Begins at adductor hiatus and runs through the popliteal fossa, posterior to PCL (can be injured here), then divides at the popliteus muscle	Superior medial and lateral geniculate	SLGA at risk in lateral release
	Inferior medial and lateral geniculate	ILGA separates lateral knee layer 3 ligaments/structures
	Middle geniculate	Supplies ACL, PCL, and synovium
	Anterior and **posterior** tibial arteries	Terminal branches of popliteal artery
• All four geniculate arteries anastomose around the knee and the patella.		
ANTERIOR TIBIAL ARTERY		
Passes b/w the two heads of the posterior tibialis into the anterior compartment and lies on interosseous membrane w/deep *peroneal* n.	Anterior tibial recurrent	Supplies and anastomoses at knee
	Circumflex fibular	Supplies fibular head and lateral knee
	Anterior medial and lateral malleolar	Supplies anterior portion of malleoli
	Dorsalis pedis	Terminal branch in foot
• Supplies muscles of the anterior compartment of the leg		
POSTERIOR TIBIAL ARTERY		
Runs with *tibial* nerve in deep posterior compartment, posterior to posterior tibialis muscle to the ankle, where it lies between the FDL and FHL tendons posterior to the medial malleolus (pulse is palpable here).	Posterior tibial recurrent	Supplies and anastomoses at knee
	Peroneal artery	Supplies lateral compartment
	Perforating muscular branches	To muscles of post. compartments
	Posterior medial malleolar	Supplies posterior medial malleolus
	Medial calcaneal	Supplies medial calcaneus/heel
	Medial and lateral plantar	Terminal branches in the foot
• Supplies muscles of the superficial and deep posterior compartments of the leg		
PERONEAL ARTERY		
Branches from posterior tibial artery, runs between PT & FHL muscles in posterior compartment	Posterior lateral malleolar	Supplies posterior lateral malleolus
	Lateral calcaneal	Supplies lateral calcaneus/heel
• Supplies muscles of the lateral compartment of the leg		
• See muscle pages 315-319 for additional pictures of the arteries		

Joint Pathology in Osteoarthritis



Knee joint opened anteriorly reveals large erosion of articular cartilages of femur and patella with cartilaginous excrescences at intercondylar notch

Progressive stages in joint pathology

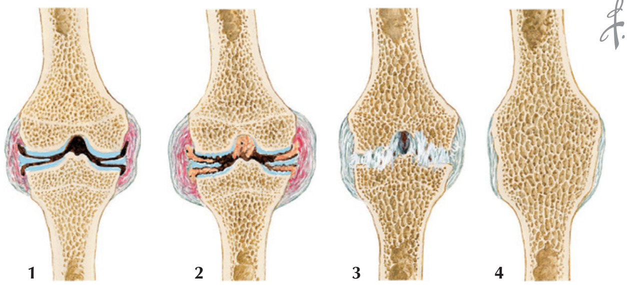


Early degenerative changes with surface fraying of articular cartilages

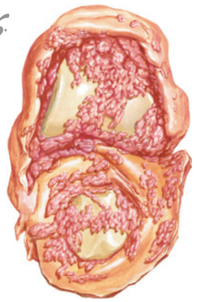
Further erosion of cartilages, pitting, and cleft formation. Hypertrophic changes of bone at joint margins

Cartilages almost completely destroyed and joint space narrowed. Subchondral bone irregular and eburnated; spur formation at margins. Fibrosis of joint capsule

Joint Pathology in Rheumatoid Arthritis



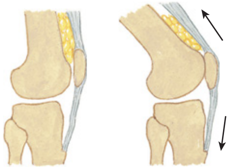
Progressive stages in joint pathology.1. Acute inflammation of synovial membrane (synovitis) and beginning proliferative changes. 2. Progression of inflammation with pannus formation; beginning destruction of cartilage and mild osteoporosis. 3. Subsidence of inflammation; fibrous ankylosis. 4. Bony ankylosis; advanced osteoporosis



Knee joint opened anteriorly, patella reflected downward. Thickened synovial membrane inflamed; polypoid outgrowths and numerous villi (pannus) extend over rough articular cartilages of femur and patella

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
ARTHRITIS			
Osteoarthritis			
• Primary/idiopathic or secondary (e.g., posttraumatic) • Loss/deterioration of articular cartilage • Can affect 1 (medial #1) or all 3 compartments in knee	**Hx:** Older, decreasing activity level. Pain w/ weight-bearing and activities **PE:** Effusion, joint line tenderness, +/– contracture or deformity (varus #1)	**XR** 1. Arthritis series ◦ Joint space narrowing ◦ Osteophytes ◦ Subchondral sclerosis ◦ Subchondral cysts 2. Alignment views	1. NSAIDs, activity modification 2. Physical therapy, brace, cane 3. Glucocorticosteroid injections 4. Unicompartmental ◦ HTO ◦ Unicompartment arthroplasty 5. Tricompartmental: Total knee arthroplasty (TKA)
Inflammatory			
• Multiple types: rheumatoid, gout, seronegative (e.g., Reiter's) • In RA, synovitis/pannus formation destroys cartilage & eventually whole joint.	**Hx:** Usually younger pts. Pain, often multiple joints **PE:** Effusion, +/– warmth, decr. ROM & deformity	**XR:** Arthritis series: joint narrowing, joint erosions, ankylosis, joint destruction **LABS:** CBC, RF, ANA, CRP, crystals, culture	1. Early: manage medically 2. Late ◦ Nonop: like osteoarthritis ◦ Synovectomy ◦ Total knee arthroplasty

Patellofemoral stress syndrome



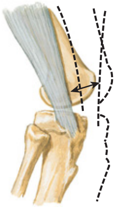
With knee extended, patella lies above and between femoral condyles in contact with suprapatellar fat pad

As knee flexes, tension in quadriceps femoris tendon and patellar tendon compresses patella against femoral condyles

Chondromalacia

Arthroscopic view shows fragmented patellar cartilage

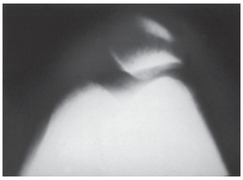
Chondromalacia of patella with "kissing" lesion on femoral condyle



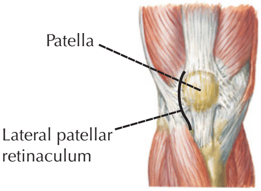
Iliotibial tract friction syndrome

As knee flexes and extends, iliotibial tract glides back and forth over lateral femoral epicondyle, causing friction

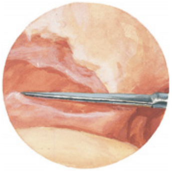
Lateral patellar compression syndrome



Preoperative x-ray showing lateral tilt of patella.



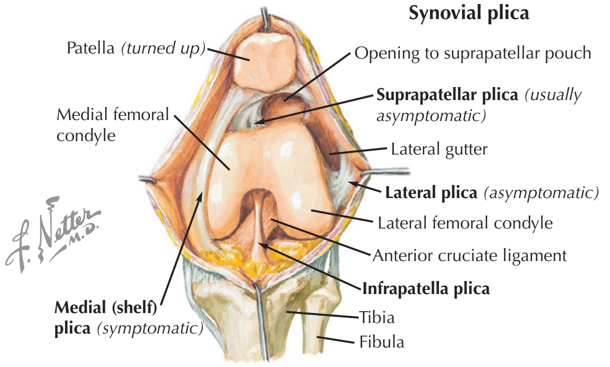
Line indicates extent of release

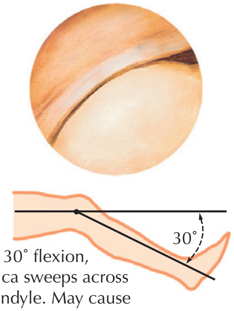


Arthroscopic view of transcutaneous release of lateral retinaculum

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
ANTERIOR KNEE PAIN			
Patellofemoral Syndrome			
• Pain in patellofemoral joint • Contributing factors: overuse, subtle instability or malalignment, quadriceps weakness • Chondromalacia may be present, but not necessarily	**Hx:** Young female and athletes. Pain w/activities (esp. running, stairs) and prolonged sitting **PE:** +patella compression, +/− incr. Q angle and/or J-sign	**XR:** 4 views: AP & notch: eval. for OCD, OA Lateral: OA & Insall ratio Sunrise: subluxation or tilt, OA, OCD	• NSAIDs, activity modification • Physical therapy: ROM, quad. strengthening, hamstring stretching, +/− foot orthoses • Patella realignment (if malalignment is present)
Chondromalacia Patellae			
• Softening or wear of the articular cartilage of the patella • Term often misused to imply any anterior knee pain	**Hx:** Usually younger pts.; pain, often multiple jts. **PE:** Effusion, decr. ROM & deformity	**XR:** 4 view: evaluate like PFS (see above)	• NSAIDs, activity modification • Physical therapy • Arthroscopic debridement/ chondroplasty may help
Lateral Patellar Compression Syndrome			
• Overloading of lateral facet during flexion • Due to tight lateral structures (esp. lateral retinaculum)	**Hx:** Usually younger pts.; anterior knee pain **PE:** PF pain, decreased mobility/patella glide	**XR:** 3 or 4 views Sunrise/merchant: evaluate for lateral patella tilt	• PT: stretch lateral tissues, quad. strengthening +/− taping or centralizing brace • Arthroscopic lateral release
Iliotibial Band Syndrome			
• ITB rubs on lateral femoral condyle • Common w/runners/cyclists	**Hx:** Pain w/activity **PE:** Lateral femoral condyle; TTP (knee at 30°)	**XR:** AP/lateral: normal, r/o tumor	• NSAIDs, activity modification, stretching (ITB) • Partial excision (rare)

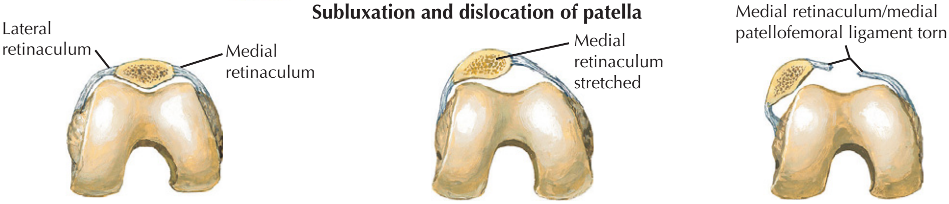
Synovial plica


Patella (turned up)
Medial femoral condyle
Medial (shelf) plica (symptomatic)
F. Netter M.D.
Opening to suprapatellar pouch
Suprapatellar plica (usually asymptomatic)
Lateral gutter
Lateral plica (asymptomatic)
Lateral femoral condyle
Anterior cruciate ligament
Infrapatella plica
Tibia
Fibula



At 30° flexion, plica sweeps across condyle. May cause pain and condylar erosion

Subluxation and dislocation of patella


Lateral retinaculum
Medial retinaculum
Medial retinaculum stretched
Medial retinaculum/medial patellofemoral ligament torn

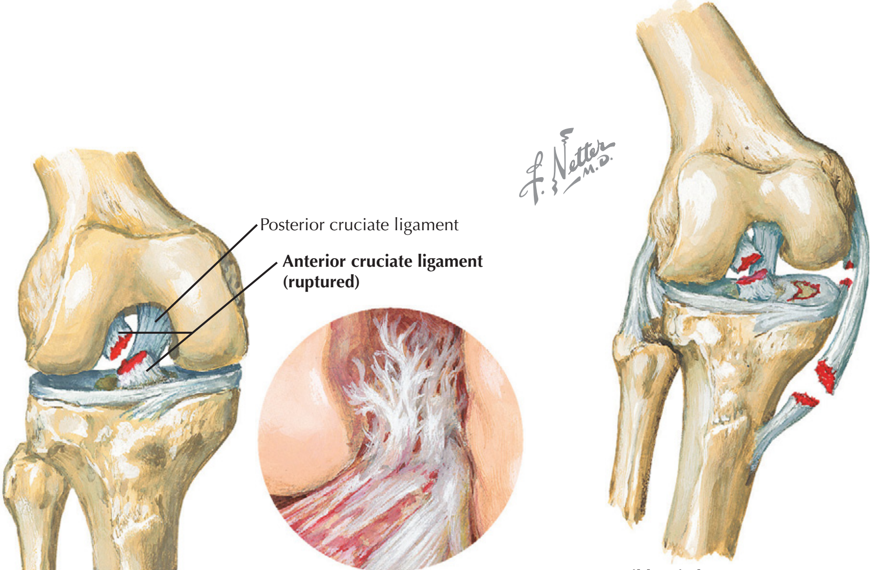
Skyline view. Normally, patella rides in groove between medial and lateral femoral condyles

In subluxation, patella deviates laterally; can be due to weakness of vastus medialis muscle, tightness of lateral retinaculum, and high Q angle

In dislocation, patella displaced completely out of intercondylar groove

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
ANTERIOR KNEE PAIN			
Patellar Instability			
• Subluxation or dislocation of patella (lateral #1) • Associated w/anatomic variants • MPFL is key structure	**Hx:** Pain & patella instability **PE:** + patellar apprehension, +/– increased Q angle, genu valgum, femoral anteversion	**XR:** 3 or 4 views: eval. for fx and patella position (lateral and/or patella alta) **MR:** eval. MPFL if acute	• Acute: MPFL repair • Recurrent/chronic: physical therapy, brace; patellar realignment surgery
Patellar Tendinitis			
• Seen in jumpers (e.g., basketball/volleyball players) • Microtears at tendon insertion at distal pole	**Hx:** Sports, anterior knee pain (worse with activity) **PE:** Patellar inferior pole TTP	**XR:** AP/lateral: normal **MR:** Increased signal at insertion (inferior pole) or intrasubstance	• NSAIDs, stretch and strengthen quadriceps and hamstrings • Surgical debridement (rare)
Plica			
• Fold in synovium (embryonic remnant) becomes thickened or inflamed • Medial plica #1	**Hx:** Anteromedial pain, +/– popping/catching **PE:** Tender, palpable plica, +/– snap with flexion	**XR:** Knee series. Eval. for other pain sources **MR:** Of questionable value	• Ice, NSAIDs • Activity modification • Arthroscopic debridement (if symptoms persist)
Prepatellar Bursitis			
• Etiology: trauma or overuse (e.g., prolonged kneeling) • "Housemaid's knee" • Inflammatory or septic	**Hx:** Knee pain & swelling **PE:** Egg-shaped swelling on anterior patella, TTP, +/– signs of infection	**XR:** Knee series: usu. normal **LAB:** CBC, ESR, +/– aspirate: gram stain & cell count	• Inflammatory: ice, NSAIDs, knee pads, rest, +/– aspiration; bursectomy if persistent • Septic: bursectomy, abx

Rupture of Anterior Cruciate Ligament

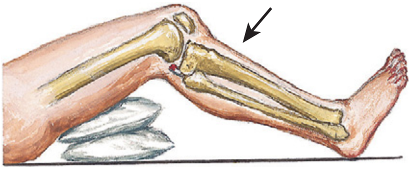

Posterior cruciate ligament
Anterior cruciate ligament (ruptured)

Arthroscopic view

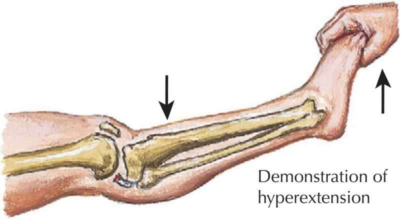
Terrible Triad
Rupture of medial collateral and anterior cruciate ligaments plus tear of medial meniscus

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
LIGAMENT INJURIES			
Anterior Cruciate			
• Mechanism: twisting injury, often noncontact pivoting • Associated with other injuries: meniscal tears, collateral ligament (all 3 = terrible triad) • Common in female athletes	**Hx:** Twisting injury, "pop," swelling, inability to continue playing **PE:** Effusion (hemarthrosis) + Lachman (most sensitive), + anterior drawer, + pivot shift	**XR:** Knee series (Segond fx is pathognomic for ACL) **MR:** Absent/detached ACL, +/− bone bruise (middle LFC–posterior lateral tibia plateau) **Arthrocentesis:** Hemarthrosis	Based on functional stability ∘ Stable/low demand pt: activity modification, PT, brace ∘ Unstable/athletes/active pt: surgical reconstruction (grafts: BTB, hamstring, allograft)
COMPLICATIONS: arthrofibrosis, failure/recurrence (1. technical error, 2. missed ligamentous injury, 3. recurrent trauma)			
Posterolateral Corner			
• Mechanism: direct blow or hyperextension/varus injury • LCL, popliteus, popliteofibular ligament are injured. These are focus of surgical reconstruction. • Can be associated w/PCL injury	**Hx:** Trauma, pain, instability **PE:** +/− effusion, + prone ER test at 30°, +/− posterolateral drawer & ER recurvatum tests	**XR:** Knee series. Avulsions can occur (fibular head). Alignment: eval. for varus **MR:** To evaluate all ligaments and other soft tissues	• Nonoperative: low grade (grades 1& 2 injury): brace & physical therapy • Surgical repair: acute grade 3 • Surgical reconstruction: chronic or combined injury, HTO if varus

Rupture of posterior cruciate ligament

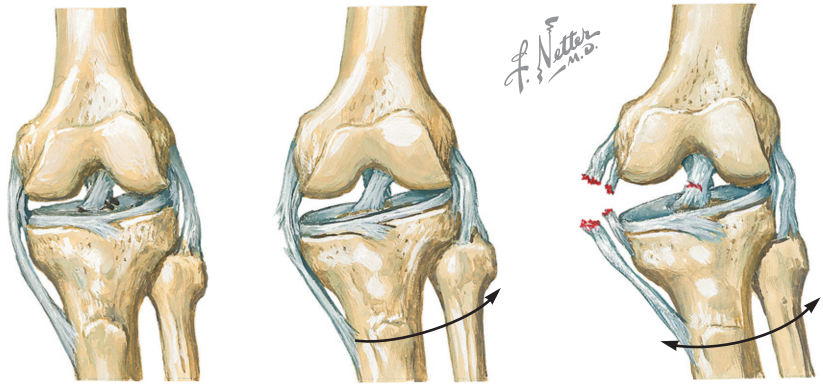


Posterior sag sign. Leg drops backward



Demonstration of hyperextension

Collateral ligament injury



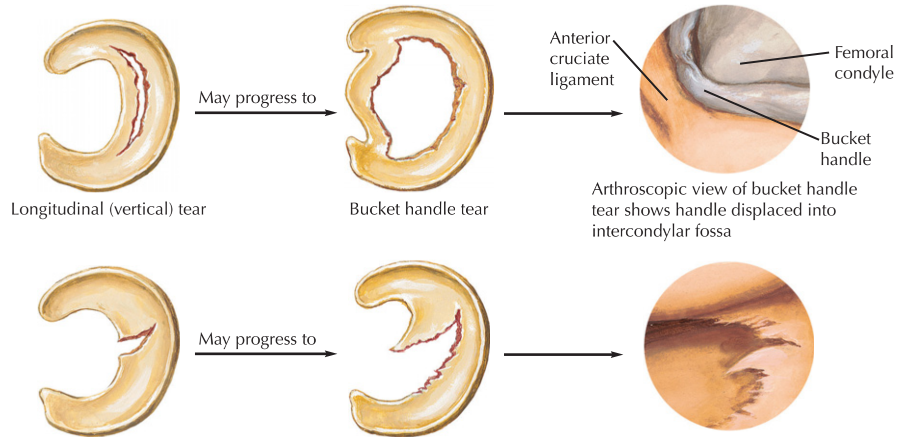
1st-degree sprain. Localized joint pain and tenderness but no joint laxity

2nd-degree sprain. Detectable joint laxity with good end point plus localized pain and tenderness

3rd-degree sprain. Complete disruption of ligaments and gross joint instability

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
LIGAMENT INJURIES			
Posterior Cruciate			
• Mechanism: anterior force on tibia (e.g., dashboard injury) or sports (hyperextension) • Associated with collateral and/or PL corner injuries	**Hx:** Trauma (dashboard) or sports injury, pain **PE:** +/− effusion, + posterior drawer, quadriceps active test, & posterior sag	**XR:** Knee series. Look for avulsion fracture. **MR:** Confirms diagnosis. Evaluates meniscus and articular cartilage.	• Nonoperative: isolated (esp. grades 1& 2 injury): brace & PT • Surgical reconstruction: failed nonop treatment, combined injury, some isolated grade 3's
Medial Collateral			
• Mechanism: valgus force • Common in football • Usually injured at femoral origin (medial epicondyle)	**Hx:** Trauma, pain, instability **PE:** Tenderness at medial epicondyle along tendon. Pain/laxity w/valgus stress	**XR:** Knee series. Medial epicondyle avulsion can occur (calcified = Pelligrini-Steida). **MR:** Confirms diagnosis	• Hinged knee brace • Physical therapy: ROM and strengthening • Surgery: uncommon
Lateral Collateral			
• Mechanism: varus force • Isolated injuries are rare, usually combined with posterolateral corner (PLC)	**Hx:** Trauma, pain, instability **PE:** Lateral tenderness. Pain/laxity w/varus stress	**XR:** Knee series. Fibular head avulsions can occur. **MR:** Confirms diagnosis	• Isolated injury: hinged brace • Combined injury: surgical repair or reconstruction

Tears of meniscus



Longitudinal (vertical) tear

Bucket handle tear

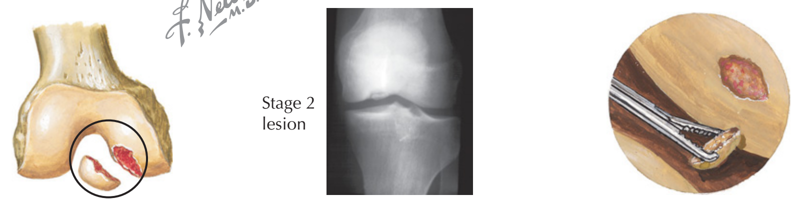
Arthroscopic view of bucket handle tear shows handle displaced into intercondylar fossa

Radial tear

Parrot beak tear

Arthroscopic view of parrot beak tear with fibrillation of meniscal margin

Osteochondral defect



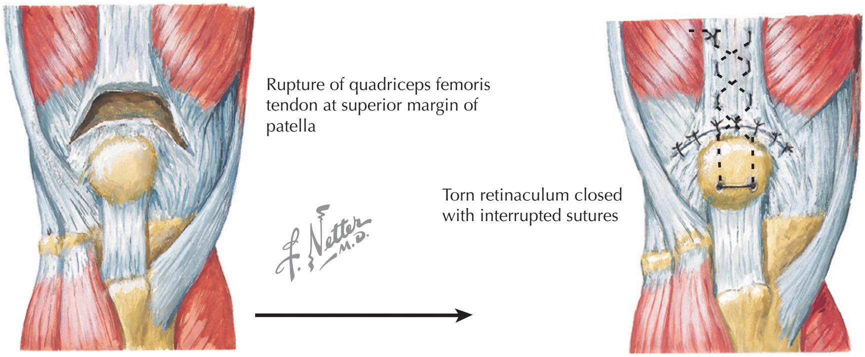
Fragment of cartilage and bone

Tunnel view radiographs of small OCD lesion involving medial femoral condyle

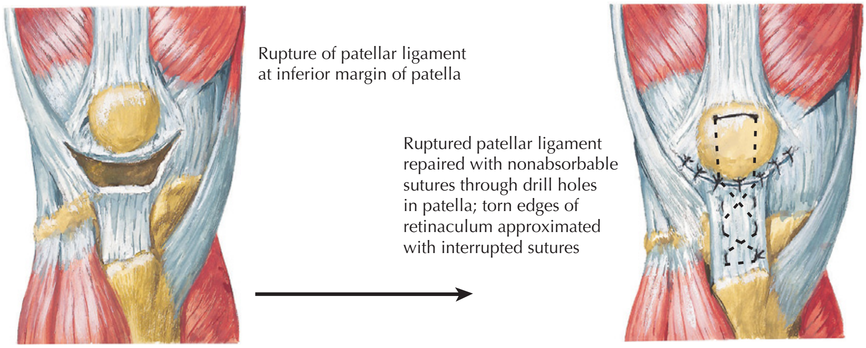
Arthroscopic view of knee with osteochondral defect

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
INTRAARTICULAR CONDITIONS			
Meniscus Tear			
• Acute: young, twisting injury • Degenerative: older +/− OA • Multiple tear patterns • Associated w/other injuries (ACL rupture, OCD, etc) • Medial>lateral 3:1 (posterior horn most common)	**Hx:** Pain & swelling esp. with flexion activities, +/− catching or locking (e.g., bucket handle tear) **PE:** Effusion, joint line tenderness, + McMurray/Apley tests	**XR:** Knee series: usually normal. Early OA often seen in pts w/degenerative tears **MR:** Very sensitive for tears. "Double PCL" sign for displaced bucket handle tears	• Small/minimally symptomatic: treat conservatively • Peripheral tears (red zone): repair (heal best w/ACL reconstruction) • Central tears (white zone): partial meniscectomy
Osteochondral Defect			
• Spectrum: purely chondral to osteochondral lesions • Traumatic or degenerative • Osteochondritis dissecans is separate but similar entity	**Hx:** Often young/active pts. Pain (usually w/WB), +/− popping, catching **PE:** Inconsistent: +/− effusion, bony tenderness	**XR:** Knee series: 4 views (need 45° PA & notch views), consider alignment series **MR:** Good modality for purely chondral lesions	Displaced OCD: internal fixation Chondral: ◦ Debridement ◦ Microfracture ◦ Osteochondral transfer ◦ Chondrocyte implantation

Quadriceps tendon rupture


Rupture of quadriceps femoris tendon at superior margin of patella
Torn retinaculum closed with interrupted sutures

Patellar tendon rupture


Rupture of patellar ligament at inferior margin of patella
Ruptured patellar ligament repaired with nonabsorbable sutures through drill holes in patella; torn edges of retinaculum approximated with interrupted sutures

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
OTHER			
Quadriceps Tendon Rupture			
• Mechanism: eccentric contraction or indirect trauma • Patients usually >40y.o. • Usually at musculotendinous junction	**Hx:** Older, fall/trauma **PE:** Effusion, palpable defect above patella. Inability to do or maintain straight leg raise	**XR:** Knee series. Look for patella baja **MR:** Will show tendon tear. Usually not needed. May be helpful in partial tears.	• Acute: primary surgical repair • Chronic: surgical reconstruction (tendon lengthening or allograft procedure)
Patellar Tendon Rupture			
• Mechanism: direct or indirect (eccentric load) trauma • Patients usually <40y.o. • Associated with underlying tendon and/or metabolic disorder	**Hx:** Younger pts, trauma, pain, loss of knee extension **PE:** Effusion, palpable defect in tendon. Cannot do straight leg raise	**XR:** Knee series. Look for patella alta **MR:** Will show tendon tear. Usually *not* needed. May be helpful in partial tears.	• Acute: primary surgical repair • Chronic: surgical reconstruction (tendon lengthening or allograft procedure)
Tumor			
#1 in adolescents: osteosarcoma; #1 in adults: chondrosarcoma; #1 benign (young adults): giant cell tumor			

TOTAL KNEE ARTHROPLASTY

General Information

- Goals: 1. Clinical: alleviate pain, maintain personal independence, allow performance of activities of daily living (ADLs) & recreation; 2. Surgical: restore mechanical alignment, restore joint line, balance soft tissues (e.g., collateral ligs.)
- Common procedure with high satisfaction rates for primary procedure. Revisions are also becoming more common. Advances in techniques and materials are improving implant survival; this procedure now available to younger pts.

Materials and Designs

Materials

- Femur component: cobalt-chrome commonly used for femoral-bearing surface with titanium stem
- Tibia component/tray: does not articulate with femoral component. Often made of titanium.
- Tibial tray insert: articulates with femoral component; made of polyethylene (UHMWPE, ultra high molecular weight PE)
  - Polyethylene (PE) wears well but does produce microscopic particles that may lead to implant loosening & failure.
  - Polyethylene should be at least 8mm thick, cross-linked for better wear, & sterilized in inert (non-O_2) environment.
  - Congruent design (not flat) improves wear rate and rollback (increased knee flexion).
  - Direct compression molding is preferred manufacturing technique.
- Cement: methylmethacrylate

Prosthetic Designs

- Unconstrained: 2 types. These are most common for primary surgical procedures with minimal deformity.
  - Posterior **c**ruciate (PCL) **r**etaining (“CR”): preserves femoral rollback for incr. knee flexion but has incr. PE wear.
  - Posterior cruciate (PCL) substituting (“**p**osterior **s**tabilized”) (“PS”): provides mechanical rollback, but may dislocate. Indicated for patellectomy, inflammatory arthritis, incompetent PCL (e.g., previous PCL rupture, etc).
- Constrained (non-“hinged”): Used for moderate ligament (MCL/LCL) deficiency. Uses a central post to provide stability.
- Constrained (“hinged”): Used for global ligament deficiency. Has high wear and failure rates.
- Other: Mobile-bearing designs are available.

Fixation

- Cement. Most common.
- Biologic. Bone ingrowth techniques. Theoretically have longer life, but have higher failure rates.

Indications

- Arthritis of knee
  - Common etiologies: osteoarthritis (idiopathic, posttraumatic), rheumatoid arthritis, osteonecrosis
  - Clinical symptoms: knee pain, worse with activity, gradually worsening over time, decreased ambulatory capacity.
  - Radiographic findings: appropriate radiographic evidence of knee arthritis

OSTEOARTHRITIS	RHEUMATOID ARTHRITIS
1. Joint space narrowing	1. Joint space narrowing
2. Sclerosis	2. Periarticular osteoporosis
3. Subchondral cysts	3. Joint erosions
4. Osteophyte formation	4. Ankylosis

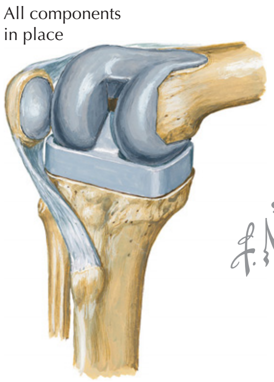
- Failed conservative treatment: NSAIDs, activity modification, weight loss, physical therapy, orthosis (e.g., medial off-loader brace), ambulatory aid (e.g., cane in contralateral hand), injections (corticosteroid, viscosupplementation)

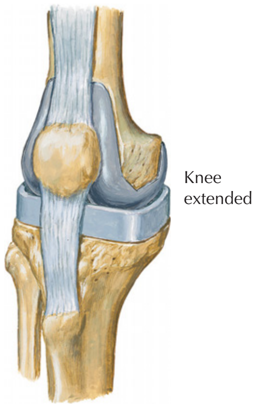
Contraindications

- **Absolute:** Neuropathic joint, infection, extensor mechanism dysfunction, medically unstable patient (e.g., severe cardiopulmonary disease). Patient may not survive the procedure.
- **Relative:** Young, active patients. These patients can wear out the prostheses many times in their lives.

Alternatives

- Considerations: age, activity level, overall medical health
- Osteotomy: relatively young patients with unicompartmental disease
  - Valgus knee/lateral compartment DJD: distal femoral varus–producing osteotomy
  - Varus knee/medial compartment DJD: proximal tibia valgus–producing osteotomy
- Unicompartmental arthroplasty: unicompartmental disease
- Arthrodesis/fusion: young laborers with isolated unilateral disease (e.g., normal spine, hip, ankle)





TOTAL KNEE ARTHROPLASTY

Procedure

Approaches

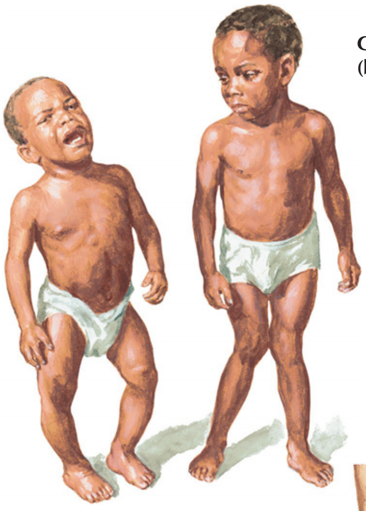
- Midline incision with medial parapatellar arthrotomy is most common.
- Minimally invasive incisions are also being used. Special equipment is often needed for the smaller incisions.

Steps

- Bone cuts
  - Cut femur and tibia perpendicular to mechanical axis. Can use intramedullary (femur/tibia) or extramedullary (tibia) reference; this will restore the mechanical alignment
  - Bone removed from femur and tibia should be equal to that replaced by the implants to maintain/restore joint line.
- Implants—trial implants are first inserted to test adequacy of the bone cuts
  - Implants should be best fit possible to native bone
  - Femur placed in 3º of external rotation to accommodate a perpendicular bone cut of the proximal tibia (typically in 3º of varus)
  - Femoral axis determined in 3 ways: 1. epicondylar axis, 2. posterior condylar axis, 3. AP axis—perpendicular to trochlea
- Balancing
  - Sagittal plane: goal is to make flexion & extension gaps equal. May need to cut more bone or add implant augments.
  - Coronal plane: soft tissues are of primary concern. Rule is to release the concave side of the deformity.
  - Varus deformity: release medial side: 1. deep MCL, 2. postmed capsule/semimemb insertion, 3.superficial MCL
  - Valgus deformity: release lateral side: 1. lateral capsule, 2a. ITB (tight in ext.), 2b. popliteus (tight in flexion), 3. LCL
  - Polyethylene trial: the knee should be stable and well balanced with the trial polyethylene in place.
- Final implantation of components

Complications

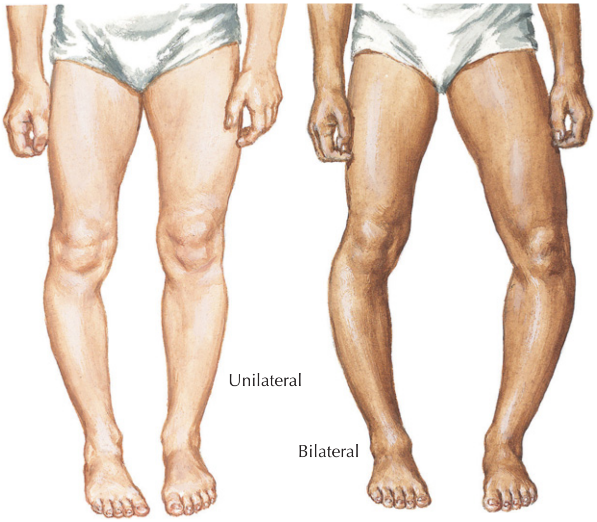
- Patellofemoral complications are most common: patella maltracking, patellofemoral pain, patellar fracture.
- Arthrofibrosis: may respond early (<6 wk) to manipulation under anesthesia.
- Extensor mechanism failure: patellar tendon rupture or avulsion (difficult to repair/reconstruct); patellar fracture
- Infection: diagnose with labs and aspiration. Prevention is mainstay: perioperative antibiotics, meticulous prep/drape technique, etc. Treatment: acute/subacute: irrigation & debridement with PE exchange. Late: 1- or 2-stage revision
- Loosening: more common with biologic fixation. Also caused by microscopic particles from polyethylene wear
- Neurovascular injury
  - Peroneal nerve: esp. after mechanical axis correction of a valgus knee (nerve is stretched)
  - Superolateral geniculate artery: should be identified and cauterized
- Medical complications: Deep venous thrombosis (DVT) and pulmonary embolus (PE) are known risks of TKA. Prophylaxis must be initiated.
- Periprosthetic fracture
  - Femur: stable implant—nail or fixed angle device; unstable implant—replace with longer stem that passes fx site



Genu varum and valgum (bow leg and knock-knee)

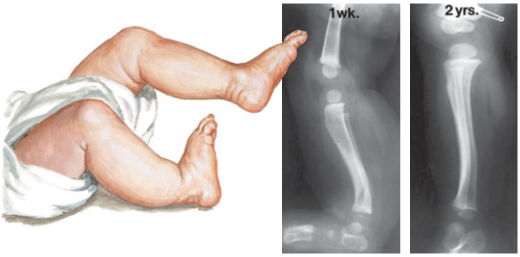
Two brothers, younger (left) with bowleg, older (right) with knock-knee. In both children, limbs eventually became normally aligned without corrective treatment

Infantile tibia vara (Blount's disease)



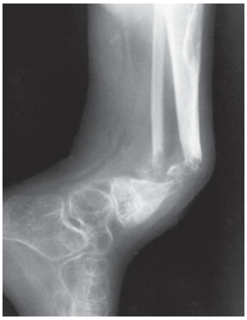
DESCRIPTION	EVALUATION	TREATMENT
GENU VARUM		
• Normal (physiologic): ages 0-2 • Pathologic: Blount's disease: 2 types ◦ Infantile: <3y.o., obesity, early walking ◦ Adolescent: insidious onset >8y.o.	**Hx:** Parents notice a deformity **PE:** Unilateral or bilateral genu varum **XR:** Tibia metadiaphyseal angle (TMDA): <9° is normal, >16° is pathologic/Blount's	• Physiologic: observation • Infantile: <3y.o.: brace; >3y.o.: osteotomy • Adolescent: hemiepiphysiodesis (open physis) or osteotomy (closed physis)
GENU VALGUM		
• Normal (physiologic): ages 2-5 • Pathologic: skeletal tumors ◦ Metabolic: renal osteodystrophy ◦ Other: trauma, infection	**Hx:** Parents notice a deformity **PE:** Unilateral or bilateral genu valgum **XR:** Alignment x-rays: valgus is 6° in normal adults	• Physiologic: observation • Pathologic: hemiepiphysiodesis or osteotomy

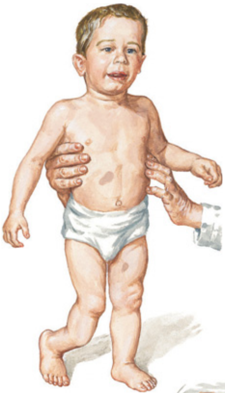
Posteromedial bowing of tibia



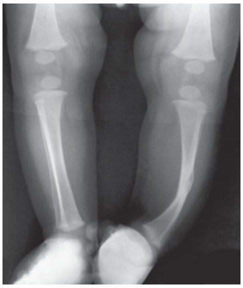
Posteromedial bowing. Convexity of bow in distal third of tibia and fibula directed posteriorly and medially. Spontaneous correction usually obviates need for realignment osteotomy, but leg-length discrepancy often persistent.

Anterolateral bowing of tibia and congenital pseudarthrosis

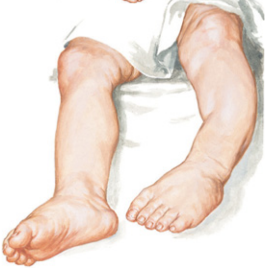




Congenital pseudoarthrosis of the tibia. Angulation of right leg. Café au lait spots on thigh and abdomen suggest relationship to neurofibromatosis.



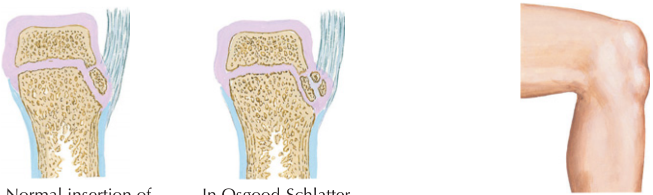
Anterolateral bowing. Medullary canal present but narrow with sclerotic changes; cyst apparent. Prone to spontaneous fracture and pseudarthrosis



Anterolateral bowing. In infancy it may be difficult to predict if anterolateral bowing will correct spontaneously or if bone will progress to fracture and congenital pseudarthrosis. Progression to pseudarthrosis is more likely if the medullary canal is narrow and has sclerotic changes.

DESCRIPTION	EVALUATION	TREATMENT
TIBIA BOWING		
Posteromedial Bowing		
• Congenital convexity of tibia • Idiopathic, unilateral • Deformity corrects but a leg length discrepancy usually results	**Hx:** Deformity present at birth **PE:** Foot appears dorsiflexed (calcaneovalgus), leg is bowed **XR:** Bowing of tibia and fibula	• Bowing resolves with growth • Resultant leg length discrepancy ◦ Mild: shoe lift ◦ Severe: hemiepiphysiodesis
Anterolateral Bowing/Congenital Tibia Pseudarthrosis		
• Bowing of tibia, unknown etiology • Associated with neurofibromatosis • Anterolateral bowing can lead to pseudarthrosis	**Hx/PE:** Leg deformity & disability. Bowed leg, +/− signs of neurofibromatosis (e.g., café au lait spots) **XR:** Reveals bowing or pseudarthrosis	• Young/bowing tibia: full contact brace • Pseudarthrosis: tibial nail/external fixation & bone graft • Amputation: if surgical treatment fails

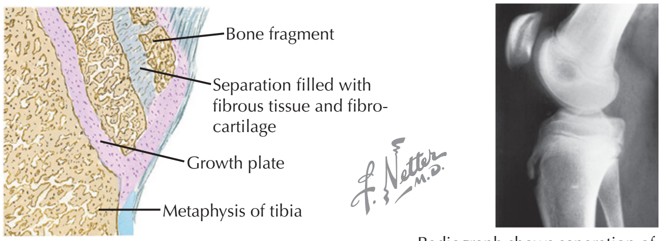
Osgood-Schlatter disease



Normal insertion of patellar ligament to ossifying tibial tuberosity

In Osgood-Schlatter lesion, superficial portion of tuberosity pulled away, forming separate bone fragments

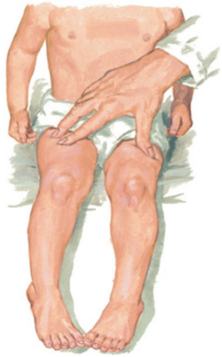
In Osgood-Schlatter condition, the apophysis of the tibial tuberosity is prominent and has irregular ossification. Fragmentation and separate ossicles may develop



High-power magnification of involved area

Radiograph shows separation of superficial portion of tibial tuberosity

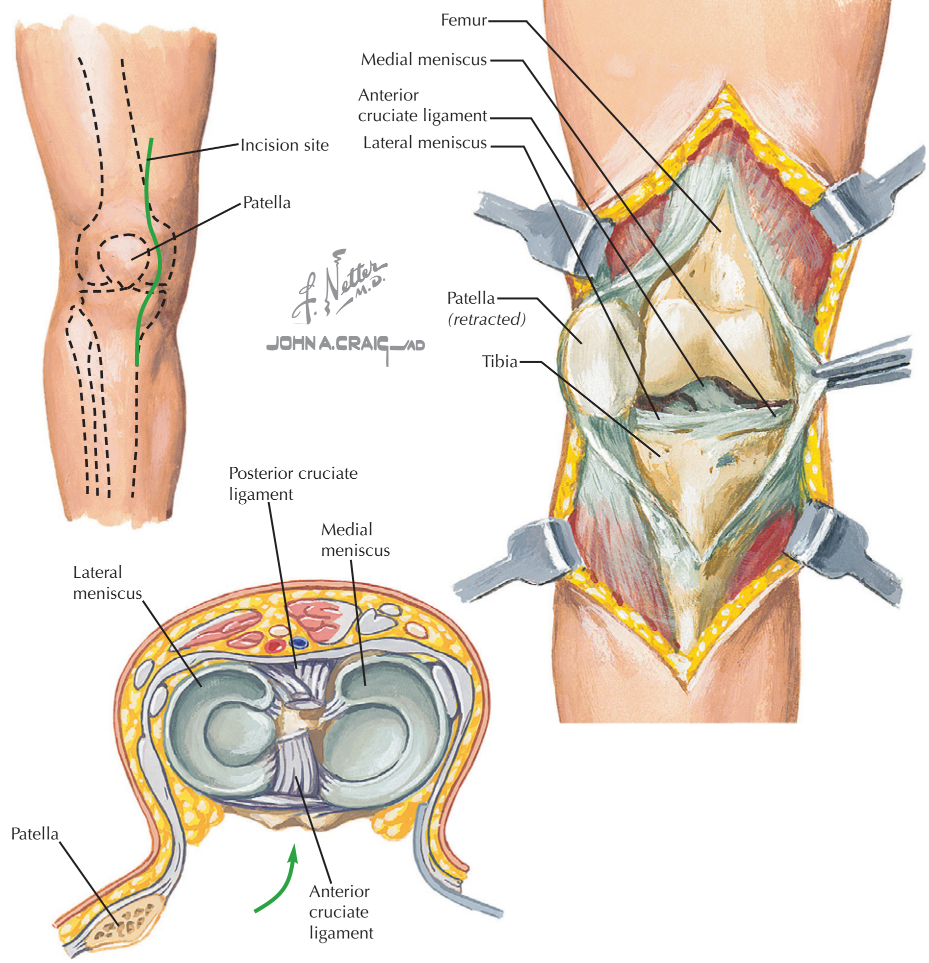
Tibial torsion



Evaluating patient for internal tibial torsion. Child seated with knees flexed 90°, heels against flat, vertical surface. Patellae point directly forward, indicating that femurs are in neutral position, but feet point inward, indicating internal tibial torsion

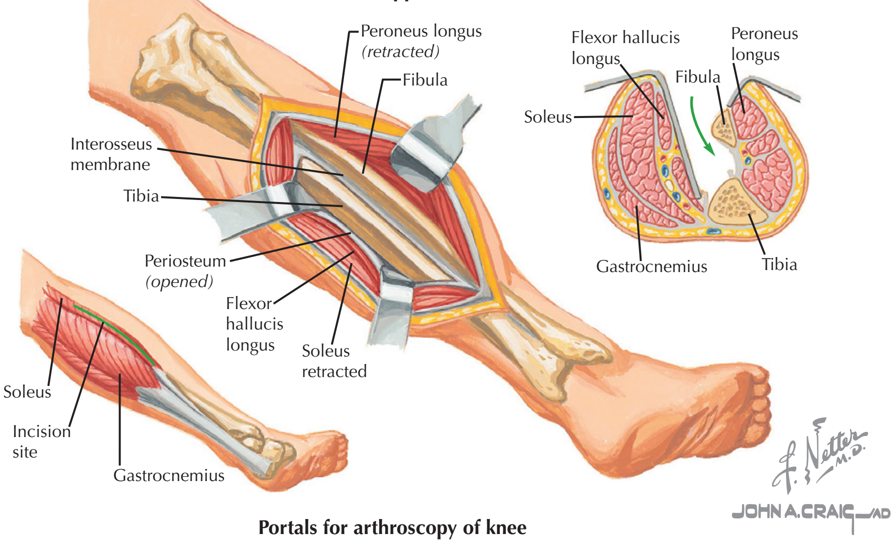
DESCRIPTION	EVALUATION	TREATMENT
OSGOOD-SCHLATTER DISEASE		
• Traction apophysitis/osteochondrosis of the tibial tubercle (2° ossification site) • Repetitive stress to extensor mechanism (e.g., in athletics [most common])	**Hx:** Adolescent w/knee pain, worse after activity **PE:** Tibial tubercle swollen & tender to palpation **XR:** Shows ossification center at tibial tubercle +/– heterotopic ossification	Symptoms resolve w/apophysis closure (during adolescence) • Activity modification/restriction • Cast/brace if symptoms severe • Excision of unfused ossicle
TIBIAL TORSION		
• Congenital internal rotation of tibia • Assoc. w/decreased intrauterine space & other "packaging problems" • Most common cause of intoeing gait	**Hx:** 1-2y.o., frequent tripping, "pigeon toed" **PE:** Intoeing gait, negative foot to thigh angle, medial foot progression angle, transmalleolar axis IR/medial with thigh/patella pointed forward	• Will spontaneously resolve • Orthoses of no proven benefit • Supramalleolar osteotomy if deformity persists into late childhood

Anteromedial Approach to Knee Joint

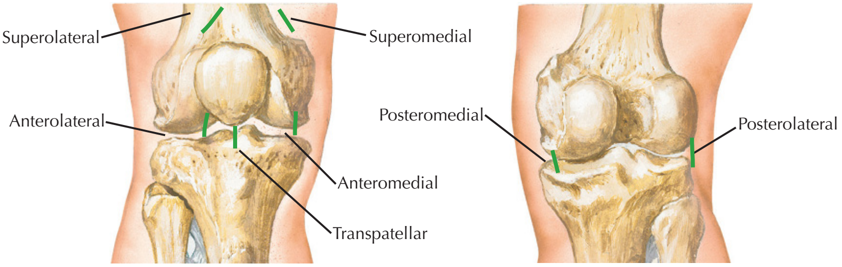

Incision site
Patella
Femur
Medial meniscus
Anterior cruciate ligament
Lateral meniscus
Patella (retracted)
Tibia
F. Netter M.D.
JOHN A.CRAIG—MD
Posterior cruciate ligament
Medial meniscus
Lateral meniscus
Patella
Anterior cruciate ligament

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
KNEE: MEDIAL PARAPATELLAR APPROACH			
• Ligament reconstruction • Total knee arthroplasty • Meniscectomy	• No planes: capsule is under skin	• Infrapatellar branch of saphenous nerve	• Most commonly used approach • Most/best exposure • Neuroma may develop from cut nerve
LEG/TIBIA: POSTEROLATERAL APPROACH (HARMON)			
• Fractures • Nonunions	• Gastrocnemius/soleus/FHL (tibial) • Peroneus longus/brevis (superficial peroneal)	• Lesser saphenous vein • Posterior tibial artery	• A technically difficult approach • Bone grafting of nonunion
FASCIOTOMY			
See pages 294 and 315			

Posterolateral approach to tibia


Peroneus longus
(retracted)
Fibula
Interosseus
membrane
Tibia
Periosteum
(opened)
Flexor
hallucis
longus
Soleus
retracted
Soleus
Incision
site
Gastrocnemius
Flexor hallucis
longus
Peroneus
longus
Fibula
Soleus
Gastrocnemius
Tibia
JOHN A.CRAIG AD

Portals for arthroscopy of knee


Superolateral
Superomedial
Anterolateral
Posteromedial
Anteromedial
Transpatellar
Posterolateral

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
ARTHROSCOPY PORTALS			
Anteromedial (inferomedial)	Just above joint line, 1cm inferior to patella; 1cm medial to patellar tendon	Anterior horn of medial meniscus	Most common portal to use instruments; also helpful for viewing lateral compartment
Anterolateral (inferolateral)	Just above joint line, 1cm inferior to patella; 1cm lateral to patellar tendon	Anterior horn of lateral meniscus	Most common portal for the arthroscope
Superolateral/ superomedial	2.5cm above joint line, lateral or medial to quadriceps tendon		Used to view patellofemoral articulation, patella tracking, also inflow/outflow
Posteromedial	Flex knee to 90°, 1cm above joint line, posterior to MCL	Saphenous nerve	Used to view PCL, posterior horns of menisci, retrieve loose bodies
Posterolateral	Flex knee, 1cm above joint line, posterior to LCL	Peroneal nerve	Used to view PCL, posterior horns of menisci, retrieve loose bodies
Transpatellar	1cm below inferior pole of patella in midline	Patellar tendon	Central joints and notch viewing

CHAPTER 10

Foot/Ankle

Topographic Anatomy 338
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Origins and Insertions 361
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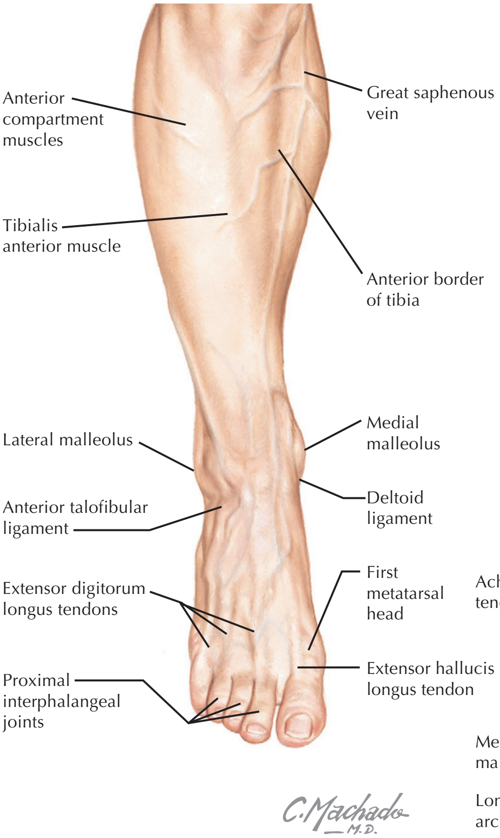
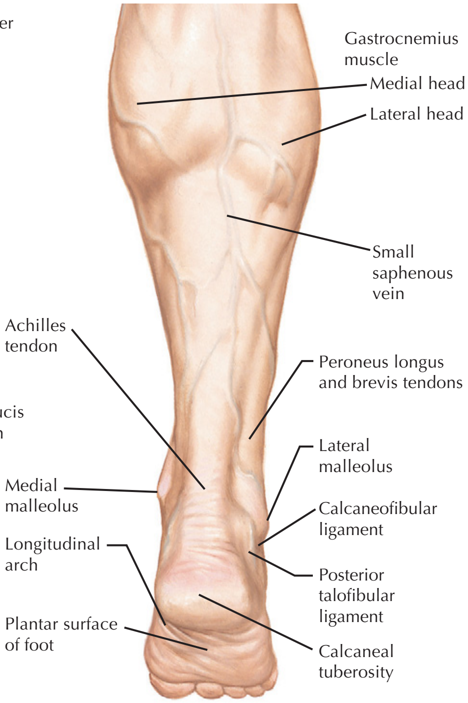
Pediatric Disorders 381
Surgical Approaches 383

Anterior view

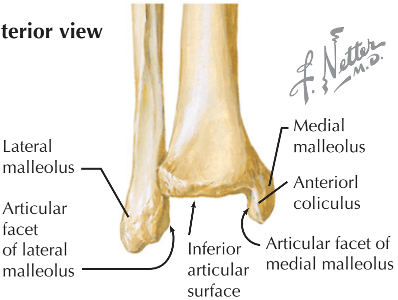

Anterior compartment muscles
Great saphenous vein
Tibialis anterior muscle
Anterior border of tibia
Lateral malleolus
Medial malleolus
Anterior talofibular ligament
Deltoid ligament
Extensor digitorum longus tendons
First metatarsal head
Extensor hallucis longus tendon
Proximal interphalangeal joints
C.Machado M.D.

Posterior view

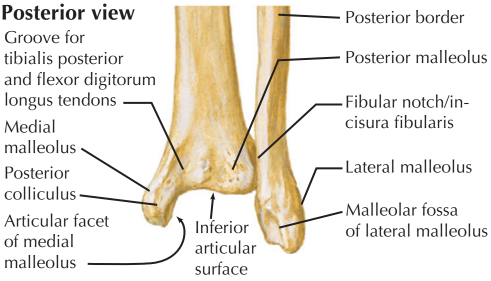

Gastrocnemius muscle
Medial head
Lateral head
Small saphenous vein
Achilles tendon
Peroneus longus and brevis tendons
Lateral malleolus
Medial malleolus
Calcaneofibular ligament
Longitudinal arch
Posterior talofibular ligament
Plantar surface of foot
Calcaneal tuberosity

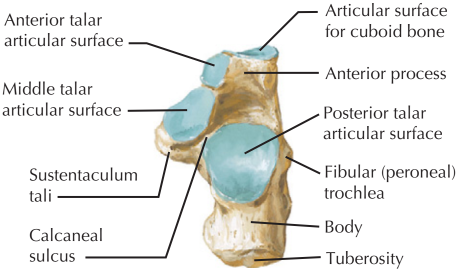
STRUCTURE	CLINICAL APPLICATION
Anterior compartment muscles	Peroneal nerve injury results in weakness and foot drop.
Gastrocnemius muscle	Muscle tears/strains commonly occur at musculotendinous junction.
Achilles tendon	Loss of contour and/or defect occurs when tendon is ruptured.
Valgus heel	Best seen posteriorly; heel should be in a valgus position.
Medial and lateral malleoli	Swelling indicates ankle injury: fracture or sprain.
Longitudinal arch of foot	Loss of arch indicates pes planus: congenital or acquired.
Plantar foot	Site of many ulcers; site of pain in plantar fasciitis.
1st metatarsal head	Head is prominent and painful in hallux valgus/bunion.
1st metatarsophalangeal joint	Common site for gout. Joint will be red and swollen.
Proximal interphalangeal joints	Hammertoes cause these joints to be prominent dorsally.

Anterior view

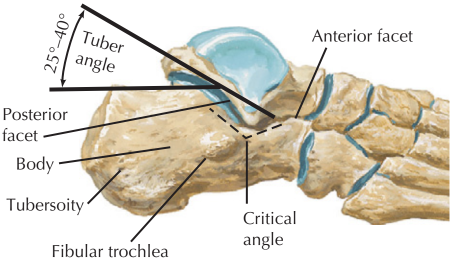

F. Netter M.D.
Lateral malleolus
Articular facet of lateral malleolus
Inferior articular surface
Medial malleolus
Anteriorl coliculus
Articular facet of medial malleolus

Posterior view


Groove for tibialis posterior and flexor digitorum longus tendons
Medial malleolus
Posterior colliculus
Articular facet of medial malleolus
Inferior articular surface
Posterior border
Posterior malleolus
Fibular notch/incisura fibularis
Lateral malleolus
Malleolar fossa of lateral malleolus

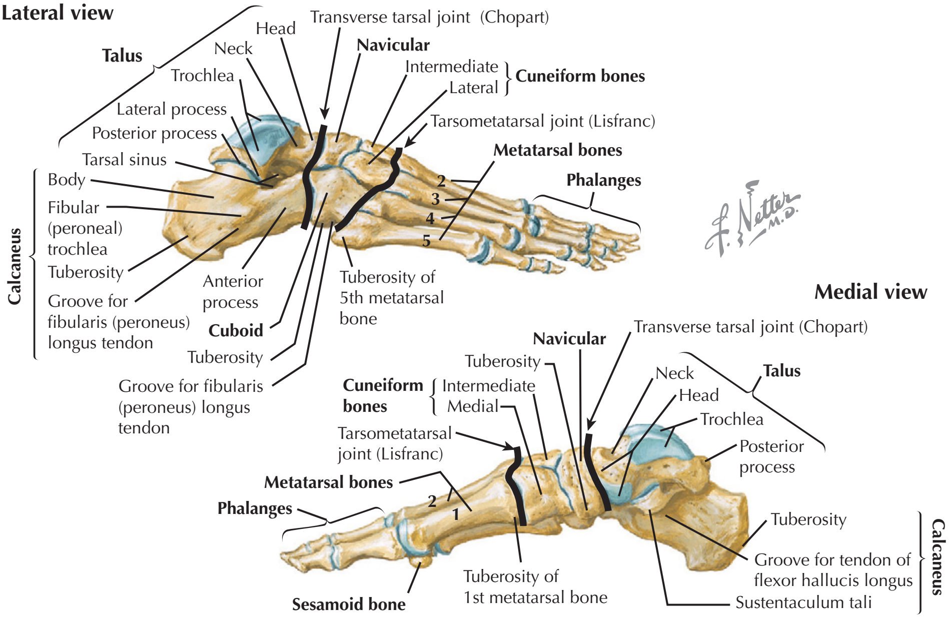

Anterior talar articular surface
Middle talar articular surface
Sustentaculum tali
Calcaneal sulcus
Articular surface for cuboid bone
Anterior process
Posterior talar articular surface
Fibular (peroneal) trochlea
Body
Tuberosity

Superior view


25°–40°
Tuber angle
Anterior facet
Posterior facet
Body
Tubersoity
Fibular trochlea
Critical angle

Lateral view

CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
DISTAL FIBULA				
Lateral malleolus	Distal physis	4yr	18-20yr	• ATFL, CFL, & PTFL all insert on lateral malleolus • Small avulsion fractures commonly occur here
DISTAL TIBIA				
Plafond: weight-bearing portion of distal tibia	Distal physis	1yr	18-20yr	• Concave and congruent with talar body/dome • Unique adolescent ankle fractures result from phased closure of distal tibia physis
Lateral distal tibia ◦ Anterior tubercle ◦ Posterior tubercle				• Incisura: lat. groove for fibula b/w 2 tubercles ◦ Called Tillaux/Chaput's tubercle; origin of AITFL ◦ Called posterior malleolus; origin of PITFL
Medial malleolus ◦ Anterior colliculus ◦ Posterior colliculus				• Deltoid ligament attaches to medial malleolus ◦ Superficial deltoid attaches to anterior colliculus ◦ Deep deltoid attaches to posterior colliculus
CALCANEUS				
Body ◦ Tuberosity ◦ Medial process ◦ Lateral process ◦ Peroneal tubercle	**Primary** Body **Secondary** Tuberosity	6mo (fetal) 9yr	13-15yr 13-15yr	• Largest tarsal bone • Provides support for lateral column of foot • Bohler's angle (normal 25-40º) • Gissane's critical angle (normal 95-105º) • Peroneal tubercle separates peroneal tendons
Sustentaculum tali				• Prominent medially, supports the medial facet • Fulcrum for FHL tendon (on inferior surface)
Multiple facets ◦ Posterior: largest ◦ Medial: on sust. tali ◦ Anterior				• Posterior facet most often involved in fractures
• Borders of ankle mortise: superior: tibia (plafond), medial: medial malleolus (tibia), lateral: lateral malleolus (fibula)				


Lateral view
Talus
Head
Neck
Trochlea
Lateral process
Posterior process
Tarsal sinus
Transverse tarsal joint (Chopart)
Navicular
Intermediate
Lateral
Cuneiform bones
Tarsometatarsal joint (Lisfranc)
Metatarsal bones
Phalanges
2
3
4
5
Calcaneus
Body
Fibular (peroneal) trochlea
Tuberosity
Groove for fibularis (peroneus) longus tendon
Anterior process
Cuboid
Tuberosity
Groove for fibularis (peroneus) longus tendon
Tuberosity of 5th metatarsal bone
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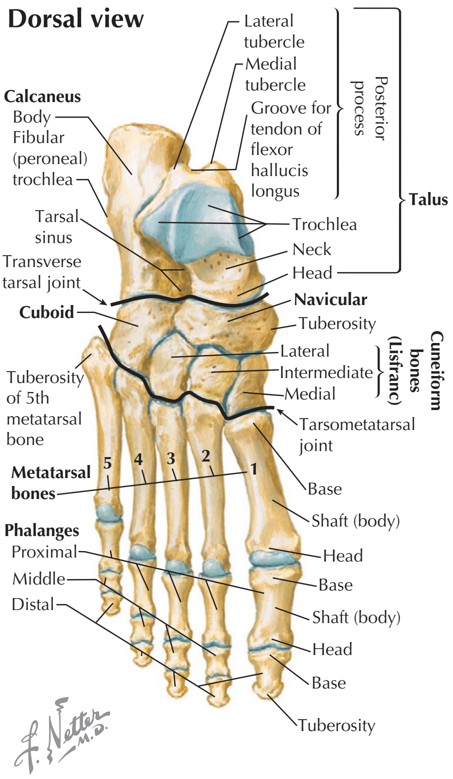
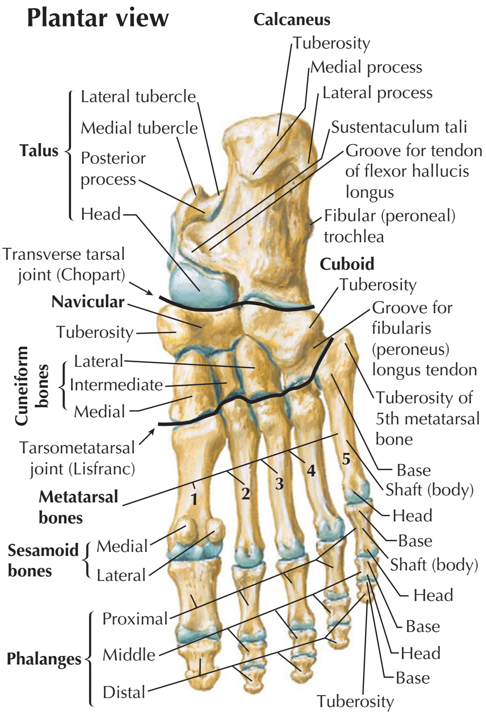
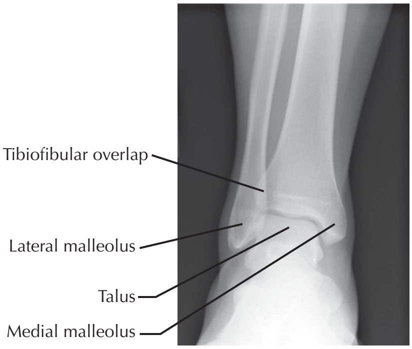
Medial view
Navicular
Transverse tarsal joint (Chopart)
Tuberosity
Cuneiform bones
Intermediate
Medial
Talus
Neck
Head
Trochlea
Posterior process
Tarsometatarsal joint (Lisfranc)
Metatarsal bones
2
1
Phalanges
Sesamoid bone
Tuberosity of 1st metatarsal bone
Tuberosity
Groove for tendon of flexor hallucis longus
Sustentaculum tali
Calcaneus

CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
		TALUS		
Head	Primary			• Talar head is supported by the spring ligament • Convex head forms tight articulation w/navicular
Neck				• Neck is site of entry for most of the blood supply
Body/trochlea (dome)	Body	7mo (fetal)	13-15yr	• Body is mostly covered with articular cartilage • AVN is a concern owing to retrograde blood supply
Posterior process Medial tubercle Lateral tubercle				• Body weight is transmitted from tibia to dome • FHL tendon runs between med. & lat.tubercles • Os trigonum may be an unfused lateral tubercle
Lateral process				• Lateral process often fractured by snowboarders
		NAVICULAR		
• Curved/ "boat" shape • Multiple facets ∘ Proximal: concave for talus ∘ Distal: facet for each cuneiform & cuboid • Tuberosity: medial/plantar	Primary	4yr	13-15yr	• Forms "acetabulum pedis" for talar head (along with strong plantar ligaments) • Is the "keystone" of the transverse arch of foot • Posterior tibialis tendon inserts on tuberosity • Susceptible to stress fracture • Kohler's disease: osteonecrosis of navicular
		CUBOID		
• Tuberosity; inferiorly • 4 facets: calcaneus, lat. cuneiform, 4th & 5th MTs • Cuboid groove; inferiorly	Primary	Birth	13-15yr	• Most lateral tarsal bone • Peroneus longus tendon passes through groove on inferior surface
		CUNEIFORMS		
• Three bones	Primary			• 2nd MT "keys" into recess of short intermediate bone; can lead to fracture of MT base
∘ Medial: largest		3yr		
∘ Intermediate: shortest		4yr	13-15yr	• TA, PL, PT tendons partially insert on medial cuneiform
∘ Lateral		1yr		
• Trapezoidal				• Trapezoidal shape strengthens transverse arch

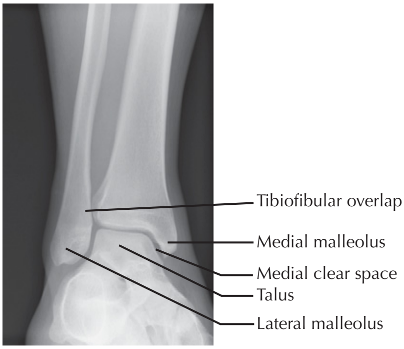

Dorsal view
Lateral tubercle
Medial tubercle
Groove for tendon of flexor hallucis longus
Posterior process
Talus
Trochlea
Neck
Head
Calcaneus
Body
Fibular (peroneal) trochlea
Tarsal sinus
Transverse tarsal joint
Cuboid
Navicular
Tuberosity
Lateral
Intermediate
Medial
Cuneiform bones (Lisfranc)
Tuberosity of 5th metatarsal bone
Tarsometatarsal joint
5
4
3
2
1
Metatarsal bones
Base
Shaft (body)
Head
Phalanges
Proximal
Middle
Distal
Base
Shaft (body)
Head
Base
Tuberosity
F. Netter M.D.


Plantar view
Calcaneus
Tuberosity
Medial process
Lateral process
Sustentaculum tali
Groove for tendon of flexor hallucis longus
Fibular (peroneal) trochlea
Talus
Lateral tubercle
Medial tubercle
Posterior process
Head
Transverse tarsal joint (Chopart)
Navicular
Tuberosity
Cuboid
Tuberosity
Groove for fibularis (peroneus) longus tendon
Tuberosity of 5th metatarsal bone
Cuneiform bones
Lateral
Intermediate
Medial
Tarsometatarsal joint (Lisfranc)
Metatarsal bones
1
2
3
4
5
Base
Shaft (body)
Head
Sesamoid bones
Medial
Lateral
Base
Shaft (body)
Head
Phalanges
Proximal
Middle
Distal
Base
Head
Base
Tuberosity

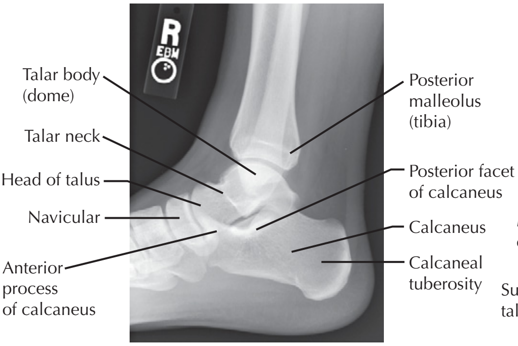
CHARACTERISTICS	OSSIFY		FUSE	COMMENTS
		METATARSALS		
• Long bone characteristics • Base of 2nd MT keys into tarsal recess • 1st MT head has crista that separates two sesamoids	**Primary** Shaft	9wk (fetal)	Birth	• Numbered medial to lateral, I to V • Only one physis per bone (in neck) except in 1st metatarsal (in base) • Peroneus brevis inserts on base of 5th MT (avulsion fracture can occur)
	Secondary Epiphysis	5-8yr	14-18y	
		PHALANGES		
• Toes 2-5 have three phalanges • Great toe has only two phalanges	**Primary** Body	10wk (fetal)	14-18yr	• 14 total phalanges in each foot • Only one physis per bone (in the base) • Sesamoid bones with other toes can occur as a normal variant (usually b/w MT head)
	Secondary Epiphysis	2-3yr	14-18yr	
• Ossification of each tarsal bone occurs from a single center (except calcaneus) • Tarsal tunnel: a fibroosseous tunnel formed by the posterior medial malleolus, medial walls of calcaneus and talus, and flexor retinaculum. Contents: tendons (TP, FDL, FHL), posterior tibial artery, tibial nerve (can be compressed in tunnel)				
		OSSICLES		
Sesamoids				• Separated by cristae plantarly (1st MT head)
Medial (tibial)				• Part of flexor mechanism (in FDB tendons)
Lateral (fibular)				• Can be fractured or dislocated
Accessory navicular				• Can cause medial foot prominence/pain
Os trigonum				• Can cause heel pain (e.g., ballet dancers)


Tibiofibular overlap
Lateral malleolus
Talus
Medial malleolus

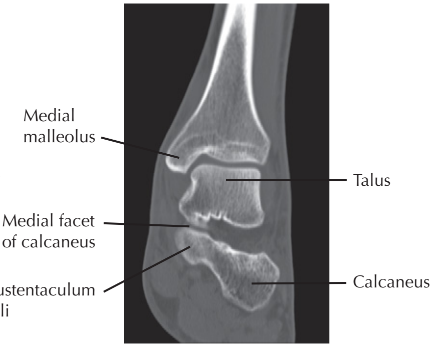
Ankle x-ray


Tibiofibular overlap
Medial malleolus
Medial clear space
Talus
Lateral malleolus

Ankle x-ray, mortise

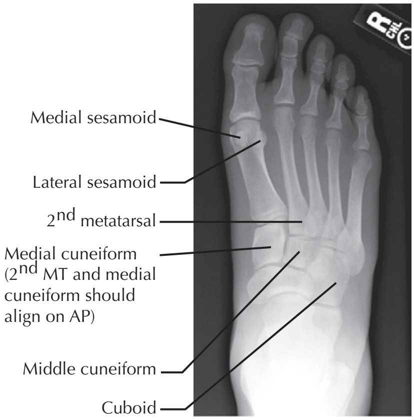

R
EBM
Talar body (dome)
Talar neck
Head of talus
Navicular
Anterior process of calcaneus
Posterior malleolus (tibia)
Posterior facet of calcaneus
Calcaneus
Calcaneal tuberosity

Ankle x-ray, lateral

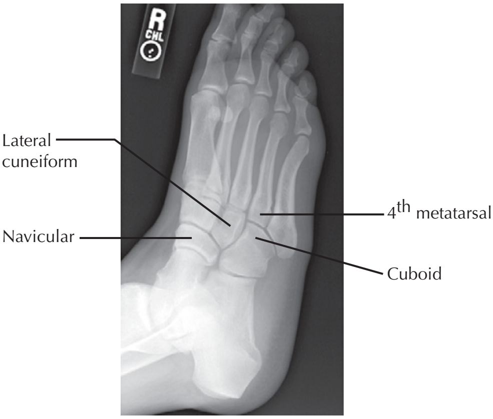

Medial malleolus
Medial facet of calcaneus
Sustentaculum tali
Talus
Calcaneus

Ankle CT, coronal

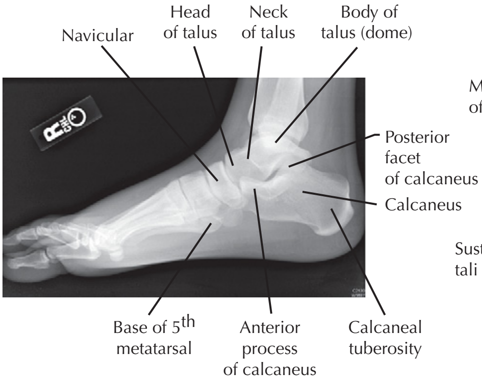
RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
		ANKLE	
Anteroposterior (AP)	Beam aimed between malleoli	Ankle (distal tibia, fibula, and talus)	Fractures, malalignment, arthritis
Lateral	Beam aimed laterally at malleolus	Tibia (anterior lip & posterior malleolus), talar dome, calcaneus, subtalar joint	Fractures: tibia, talus, calcaneus; Bohler's angle (nl: 25-40°)
Mortise view	AP with 15° of internal rotation	Best view of ankle mortise, plafond	Fractures; widening = ligament injury
Stress view	Mortise with external stress	ER: syndesmosis widening (nl <6mm) Medial clear space widening (nl<4mm) Inversion/tilt: joint space widening Anterior/drawer: ant. talus subluxation	ER: syndesmosis injury, deltoid ligament injury Inv: lateral ligament (CFL) injury Ant: lateral ligament (ATFL) injury
		OTHER STUDIES	
CT	Axial, coronal, sagittal	Articular congruity, fracture fragments	Intraarticular or comminuted fxs
MRI	Sequence protocols vary	Ligaments, tendons, and cartilage	OCD lesions, ligament or tendon tears
Bone scan		All bones evaluated	Stress fractures, infection


Medial sesamoid
Lateral sesamoid
2nd metatarsal
Medial cuneiform (2nd MT and medial cuneiform should align on AP)
Middle cuneiform
Cuboid
R CHL

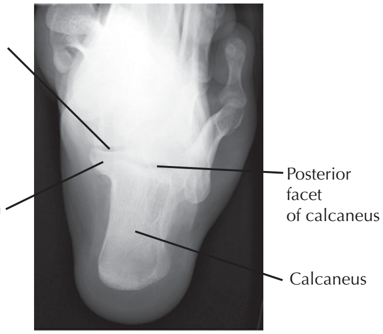
Foot x-ray, AP


Lateral cuneiform
Navicular
4th metatarsal
Cuboid
R CHL

Foot x-ray, oblique


Navicular
Head of talus
Neck of talus
Body of talus (dome)
Posterior facet of calcaneus
Calcaneus
Base of 5th metatarsal
Anterior process of calcaneus
Calcaneal tuberosity
R CHL

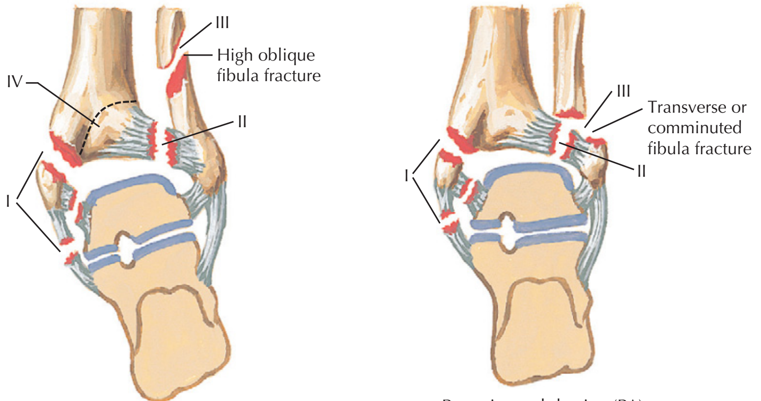
Foot x-ray, lateral


Medial facet of calcaneus
Sustentaculum tali
Posterior facet of calcaneus
Calcaneus

Foot x-ray, calcaneus

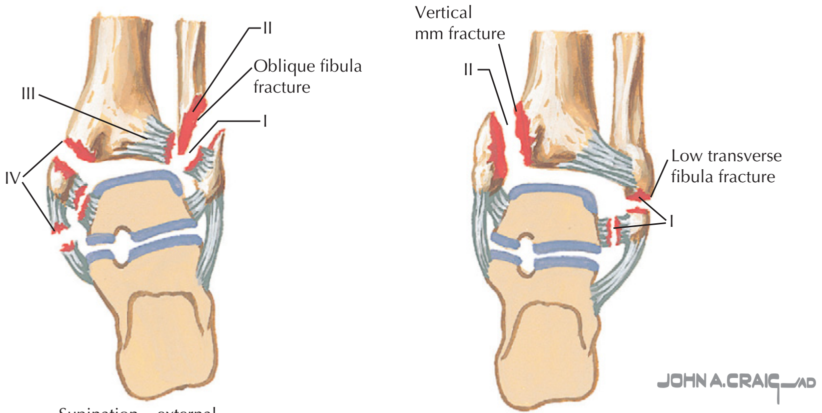
RADIOGRAPH	TECHNIQUE	FINDINGS	CLINICAL APPLICATION
		FOOT	
Anteroposterior (AP)	Beam perpendicular to midfoot; WB used to evaluate deformity	Tarsals, metatarsals, and phalanges; 2nd MT should align w/medial cuneiform	Fractures/dislocations mid & forefoot; used to measure hallux valgus angles
Lateral	Beam aimed laterally at tarsals	Hind, mid, and forefoot	Fractures and dislocations
Oblique	AP with 45° of internal rotation	Mid & forefoot, TMT jt.	4th MT aligns with cuboid
Harris	DF foot, beam 45° to heel	Calcaneal tuberosity, post. facet	Calcaneus fractures
Canale	15° foot eversion, tilt beam 15°	Talar neck	Talar neck fractures
Broden	IR leg 40°, tilt beam 10, 20, 30, 40°	Posterior subtalar facet	Fx of posterior facet or sustentaculum
Stress views	AP with abd/add or inv/eversion	Bony and joint alignment	Lisfranc fracture/dislocations
Axial/sesamoid view	DF hallux, beam along foot axis	Shows sesamoid bones/ articulation	Sesamoid fracture or dislocation

Lauge-Hansen Classification of Ankle Fractures


III
High oblique fibula fracture
IV
II
I
III
Transverse or comminuted fibula fracture
I
II

Pronation – external rotation (PER)

Pronation – abduction (PA)

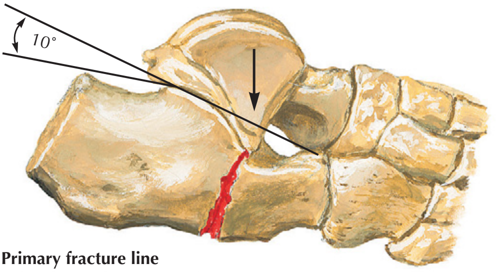

II
Oblique fibula fracture
III
I
IV
Vertical mm fracture
II
Low transverse fibula fracture
I
JOHN A.CRAIG_AD

Supination – external rotation (SER)

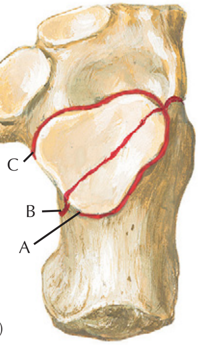
Supination – adduction (SA)

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
ANKLE FRACTURE			
• Very common in all ages • One or both malleoli involved • 1 malleolus fx: usually stable • Bimalleolar fx OR lateral malleolus fx with medial ligament rupture: unstable • Congruent mortise required • Fibular length & rotation must be correct	**Hx:** Trauma, pain, swelling, +/– inability to bear weight **PE:** Effusion, soft tissue swelling. One or both malleoli TTP +/– proximal fibula tenderness **XR:** Ankle trauma series **Stress XR:** If stability of fx is in question (esp. Weber B/SER II)	**Weber/AO:** location of fibula fx **A:** distal to plafond **B:** at the plafond **C:** above the plafond **Lauge-Hansen:** based on foot position & mechanism **SA:** supination/adduction I-II **SER**: supination/ER I-IV **PER:** pronation/ER I-IV **PA:** pronation/abduction I-III	• Dislocation: reduce joint immediately • Stable/nondisplaced/avulsion: short leg cast for 4-6wk • Unstable/displaced: ORIF. Restore congruent mortise & fibular length. Add syndesmosis fixation for unstable syndesmosis.
COMPLICATIONS: Posttraumatic osteoarthritis/pain, limited range of motion, nonunion/malunion, instability, RSD			
See Chapter 9, Knee/Leg for pilon fracture and Maisonneuve fracture			

Intraarticular Fracture of Calcaneus



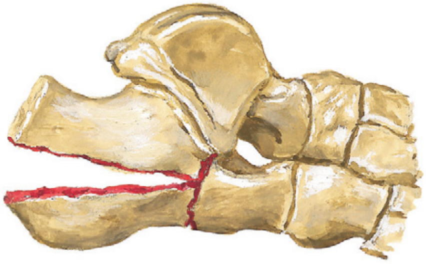
Primary fracture line
Talus driven down into calcaneus, usually by fall and landing on heel. Böhler angle narrowed



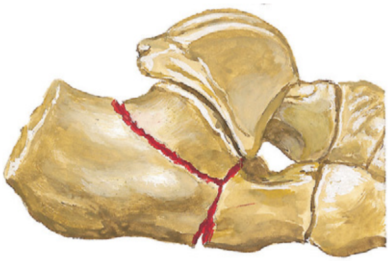
Primary fracture line runs across posterior facet, forming anteromedial and posterolateral fragments

Saunders classified this fratcture A-C (lateral to medial)

Essex-Lopresti



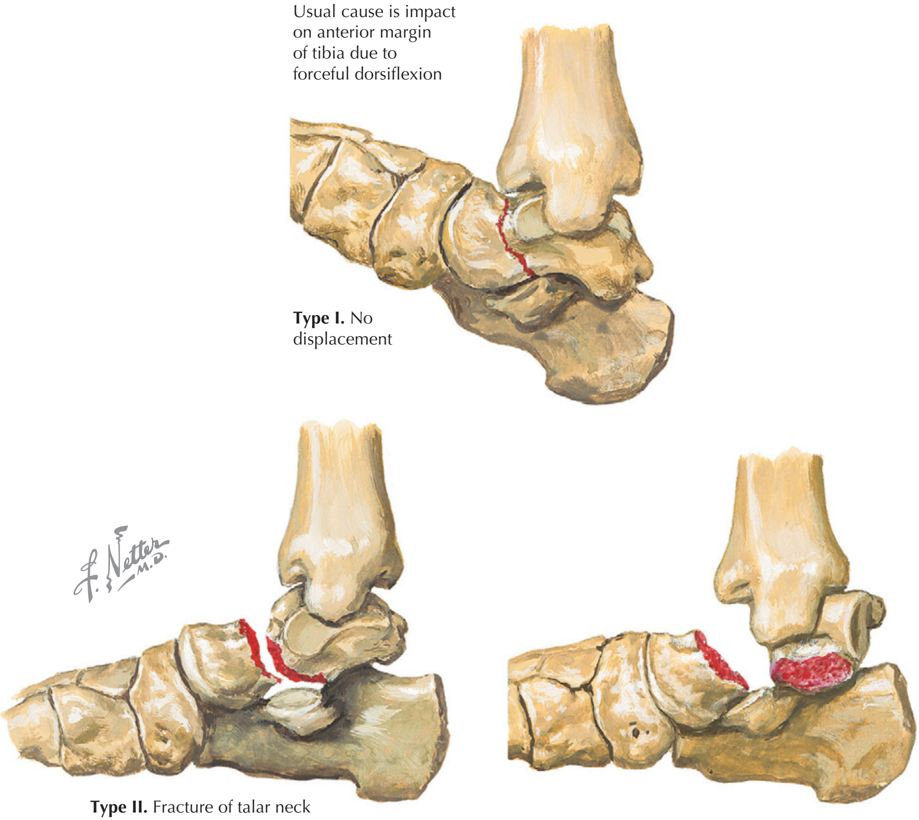
Secondary fracture line
Often extends through tuberosity of calcaneus to produce **tongue-type fracture**



If secondary fracture line extends to dorsal aspect of calcaneus, **joint depression-type** fracture results

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
CALCANEUS FRACTURE			
• Most common tarsal fracture • Mechanism: high energy/axial load (e.g., MVA, high fall) • Most fractures intraarticular • Intraarticular fractures affect subtalar joint (esp. posterior facet) • Skin at risk from extensive edema • Rule out spine injury in a fall • Associated with poor outcomes and long-term disability	**Hx:** Trauma, pain, swelling, inability to bear weight **PE:** Marked edema & arch swelling, +/– fx blisters. Widened heel. Check nerve function and pulses. **XR:** AP, lateral (Böhler's angle nl 25-40°), Harris view **CT:** To better define fx lines, displacement, comminution	**Extraarticular** • Body, tuberosity, anterior or medial process, sustentaculum tali **Intraarticular** • ***Essex-Lopresti*** ◦ Joint depression ◦ Tongue type • ***Sanders:*** per coronal CT ◦ I-IV: how many fragments/fracture lines? ◦ A-C: lateral to medial	**Extraarticular** • Nondisplaced: cast 10-12wk • Displaced: perc. pinning **Intraarticular** • Nondisplaced: cast 12 wk • Displaced: ORIF • Comminuted, low demand/elderly, smokers: closed reduction, cast • Comminuted, laborer: primary subtalar fusion
COMPLICATIONS: Skin/wound slough (delay surgery until edema has resolved), malunion (varus), subtalar OA, pain			

Fracture of Talar Neck



Usual cause is impact on anterior margin of tibia due to forceful dorsiflexion

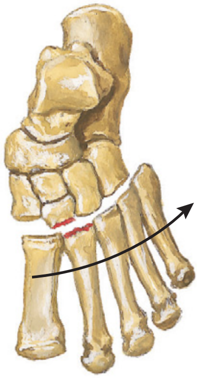
Type I. No displacement

Type II. Fracture of talar neck with subluxation or dislocation of subtalar joints

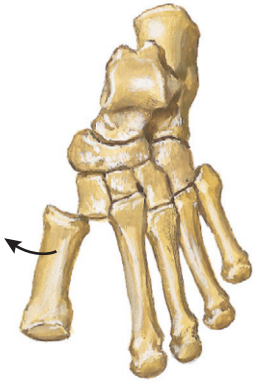
Type III. Fracture of talar neck with dislocation of subtalar and tibiotalar joints

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
TALUS FRACTURE			
• Mechanism: high energy (e.g., MVA, fall from height) • Neck fractures #1 • Talus has tenuous blood supply • Neck fx can result in AVN • Displaced neck fractures are a surgical emergency • AVN decreased with ORIF • Hawkins sign = no AVN • Lateral process fx: snowboarders	**Hx:** Trauma, pain, swelling, inability to bear weight **PE:** Edema, tenderness, +/− deformity. Check pulses. **XR:** AP, lateral, Canale (neck) & Broden (post. facet) views **Hawkins sign**: resorption of subchondral bone (lucency on XR) indicates fracture healing **CT:** To better define fx lines	**Body** (dome) Osteochondral fx/injury **Head** **Process:** lateral, posterior **Neck:** Hawkins (predicts risk of AVN) I: Nondisplaced (<10%) II: Subtalar dx (40%) III: II + tibiotalar dx (90%) IV: III + talonavicular dx (100%)	**Body/head/process fractures** • Nondisplaced: cast • Displaced: ORIF **Osteochondral fx/injury** • Large bony piece: repair • Small/mostly cartilaginous: arthroscopic debride/drilling **Neck fractures** • Type I: percutaneous pin • Types II-IV: ORIF
COMPLICATIONS: Ankle or subtalar osteoarthritis/pain, malunion (varus #1), osteonecrosis, arthrofibrosis/stiffness			

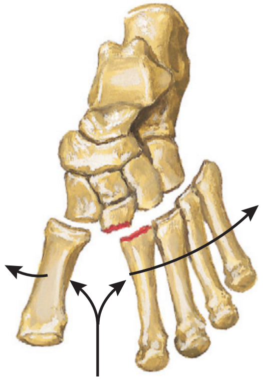
Lisfranc fracture/dislocation



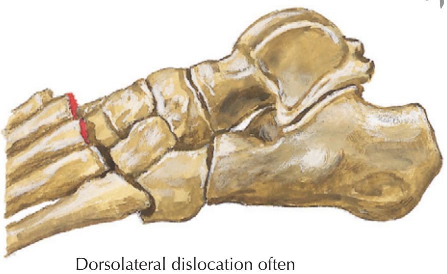
Homolateral dislocation. All five metatarsals displaced in same direction. Fracture of base of 2nd metatarsal



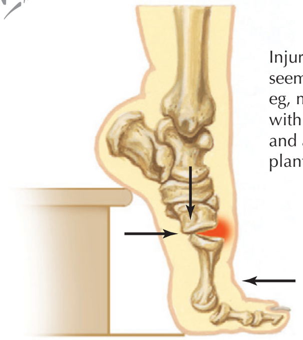
Isolated dislocation. One or two metatarsals displaced; others in normal position



Divergent dislocation. 1st metatarsal displaced medially, others superolaterally

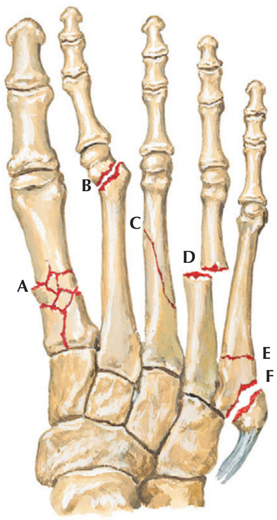


Dorsolateral dislocation often best seen in lateral view

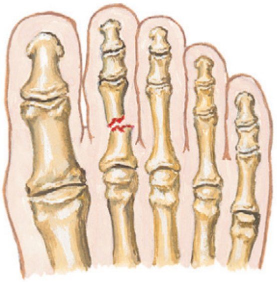


Injury may occur from seemingly trivial event, eg, misstep into a hole with axial compression and abduction force on plantarflexion foot.

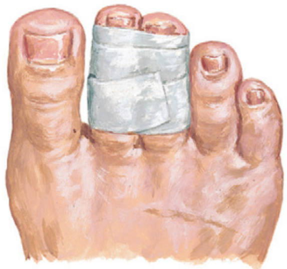
DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
TARSOMETATARSAL (LISFRANC) FRACTURE/DISLOCATIONS			
• Mechanism: torque of fixed foot or axial load to vertical foot • Recessed 2nd MT base gives stability to joint • Can have fx or purely ligamentous injury • "Fleck" sign is avulsion of Lisfranc ligament from 2nd MT base • Easily missed injury • Assoc. w/other injuries including tarsal fractures	**Hx:** Trauma to planted foot, pain, swelling **PE:** Edema & ecchymosis. Careful vascular exam. **XR:** AP, lateral, oblique; >2mm b/w 2nd MT base and cuneiform is pathologic. WB/stress views if needed; consider comparison view **CT:** Usually not needed	**By direction** • Isolated: a single metatarsal is affected (usu. 1st or 2nd) • Homolateral: all metatarsals dislocate in same direction • Divergent: metatarsals dislocate in different directions *Many different combinations are possible.*	**Nondisplaced (no widening)** • NWB cast: 8wk • >2mm needs surgical fixation **Minimally displaced** • Closed reduction and percutaneous pinning **Displaced** • ORIF (screws and K-wires) • External fixation if needed preliminarily
COMPLICATIONS: Posttraumatic arthritis/pain, altered gait/limp, compartment syndrome (1st intermetatarsal br. of DPA)			



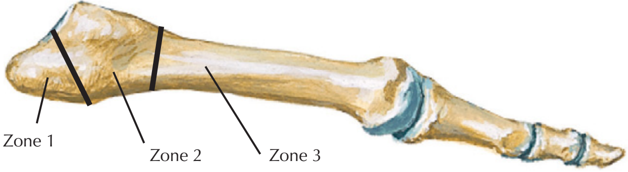
Types of fractures of metatarsal: A. Comminuted fracture. B. Displaced neck fracture. C. Oblique fracture. D. Displaced transverse fracture. E. Fracture of base of 5th metatarsal. F. Avulsion of tuberosity of 5th metatarsal



Fracture of proximal phalanx

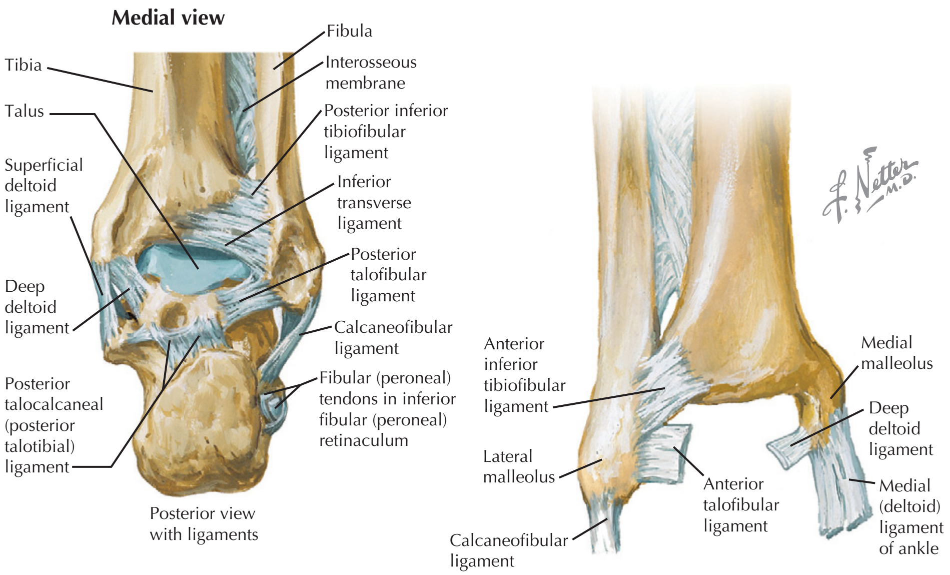


Fracture of phalanx splinted by taping to adjacent toe (buddy taping)



Proximal fifth metatarsal fracture

DESCRIPTION	EVALUATION	CLASSIFICATION	TREATMENT
METATARSAL FRACTURES			
• Common injuries: most benign • Prox. 5th MT is watershed area. Nutrient artery injury can result in nonunion • Prox. 5th MT avulsion fx by lateral plantar aponeurosis or peroneus brevis tendon • Stress fractures in runners	**Hx:** Trauma, pain, swelling **PE:** Edema & ecchymosis, TTP **XR:** AP, lateral, oblique **BS:** To evaluate for stress fx	**Location:** Head, neck, shaft, base **5th MT base fracture:** Zone 1: avulsion fx Zone 2: metadiaphyseal jxn Zone 3: proximal diaphysis	• Nondisplaced: hard shoe/cast • Displaced/angulated: PCP or ORIF • 5th MT base: ◦ Zone 1: hard shoe ◦ Zone 2: SLNWC 6-8wk ◦ Zone 3: SLNWC 8wk/ORIF; zones 2&3: ORIF in elite athletes
COMPLICATIONS: Nonunion (esp. proximal 5th metatarsal), malunion, posttraumatic osteoarthritis/pain			
PHALANGEAL FRACTURES			
• Common injuries: most benign • Usually from "stubbing" toe or dropping object on toe • Rarely need surgical treatment	**Hx:** Trauma, pain, swelling **PE:** Edema & ecchymosis, TTP **XR:** AP, lateral, oblique	**Location** Head Shaft Base	• Non/minimally displaced: buddy tape & hard shoe • Displaced/unstable: PCP • Intraarticular hallux fx: ORIF


Medial view
Tibia
Talus
Superficial deltoid ligament
Deep deltoid ligament
Posterior talocalcaneal (posterior talotibial) ligament
Fibula
Interosseous membrane
Posterior inferior tibiofibular ligament
Inferior transverse ligament
Posterior talofibular ligament
Calcaneofibular ligament
Fibular (peroneal) tendons in inferior fibular (peroneal) retinaculum
Posterior view with ligaments
Anterior inferior tibiofibular ligament
Lateral malleolus
Calcaneofibular ligament
Anterior talofibular ligament
Medial malleolus
Deep deltoid ligament
Medial (deltoid) ligament of ankle
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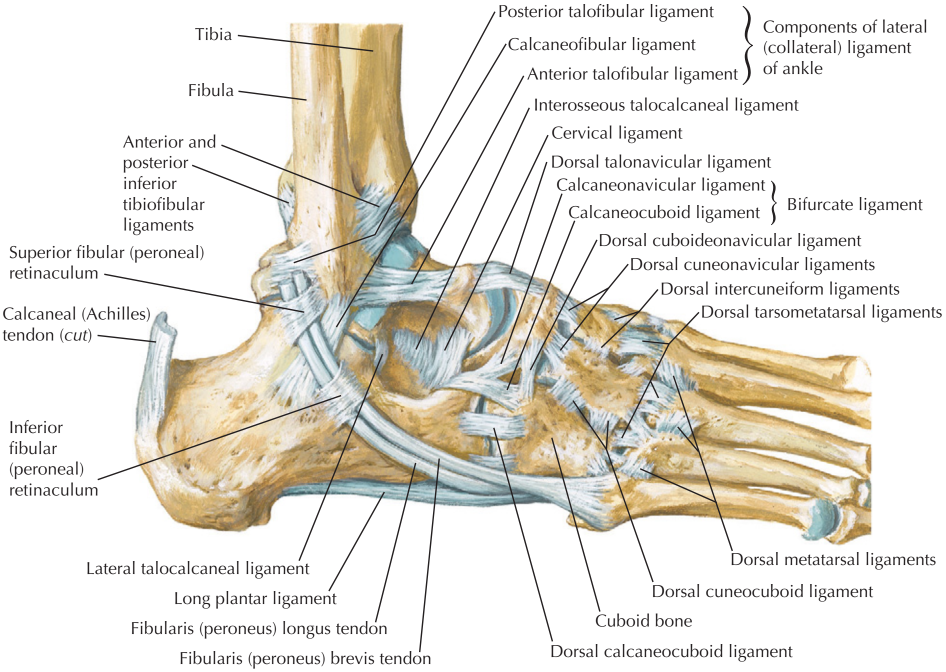
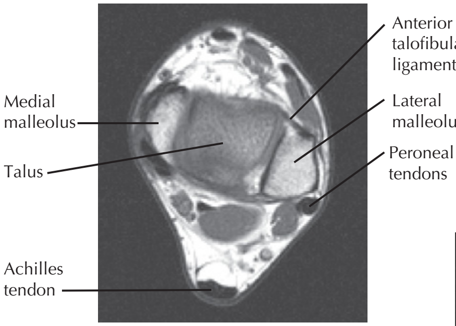
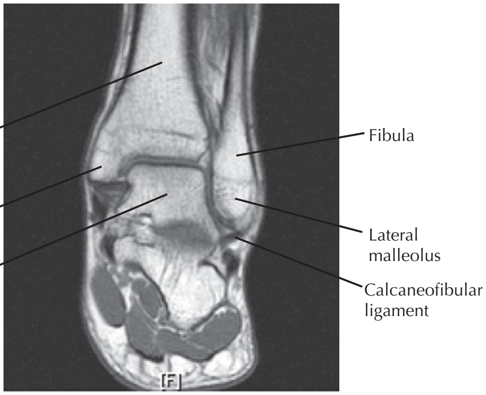
LIGAMENTS	ATTACHMENTS	COMMENTS
DISTAL TIBIOFIBULAR		
Syndesmosis	Primary support of ankle	Injured in Weber C fx & "high" ankle sprains
◦ Anterior inferior tibiofibular (AITFL)	Anterior tibia (ant. tubercle) to distal fibula	Strong, oblique ligament. Avulsion yields "Tillaux" fracture/fragment
◦ Posterior inferior tibiofibular (PITFL)	Posterior tibia to distal fibula	Weaker; originates on posterior malleolus
◦ Inferior transverse ligament (ITL)	Inferior & deep to PITFL	Gives posterior support to ankle mortise
◦ Interosseous ligament (IOL)	Lateral tibia to medial fibula	Strong distal thickening of interosseous memb.
If the syndesmosis is torn, the ankle mortise is disrupted. The fibula (& firmly attached talus) will displace laterally.		
ANKLE		
The ankle is ginglymus, or hinge joint. It primarily provides plantarflexion & dorsiflexion motion. ROM: DF 20°, PF 50°		
Capsule	Tibia and fibula to talus	Gives varying amount of support to the ankle
Lateral	Lateral malleolus to:	ATFL & PTFL are capsular thickenings
◦ **Anterior talofibular** (ATFL)	Neck of talus	Resists anterior translation. #1 injured ligament in ankle sprains.
◦ **Calcaneofibular** (CFL)	Calcaneus (peroneal tub.)	Deep to peroneal tendons. Resists inversion. #2 in ankle sprains.
◦ Posterior talofibular (PTFL)	Talus (posterior process)	Strong. Rarely torn. Attaches to lateral tubercle of posterior process.
Medial: deltoid ligament (4 parts)		Origin on medial malleolus (MM)
Superficial deltoid	Anterior colliculus of MM to:	Resists eversion of the ankle
◦ Anterior tibiotalar	Anteromedial talus	Weak ligament. Can cause impingement
◦ Tibionavicular	Navicular tuberosity	Restraint to medial migration of talar head
◦ Tibiocalcaneal	Sustentaculum tali	Strongest portion of the superficial deltoid, resists valgus
Deep deltoid	Posterior colliculus of MM to:	Resists external rotation and lateral migration
◦ Posterior tibiotalar	Medial talus & medial tubercle	Nearly horizontal; strongest portion of deltoid

Right foot: lateral view


Posterior talofibular ligament
Calcaneofibular ligament
Anterior talofibular ligament
Components of lateral (collateral) ligament of ankle
Interosseous talocalcaneal ligament
Cervical ligament
Dorsal talonavicular ligament
Calcaneonavicular ligament
Calcaneocuboid ligament
Bifurcate ligament
Dorsal cuboideonavicular ligament
Dorsal cuneonavicular ligaments
Dorsal intercuneiform ligaments
Dorsal tarsometatarsal ligaments
Tibia
Fibula
Anterior and posterior inferior tibiofibular ligaments
Superior fibular (peroneal) retinaculum
Calcaneal (Achilles) tendon (*cut*)
Inferior fibular (peroneal) retinaculum
Lateral talocalcaneal ligament
Long plantar ligament
Fibularis (peroneus) longus tendon
Fibularis (peroneus) brevis tendon
Dorsal metatarsal ligaments
Dorsal cuneocuboid ligament
Cuboid bone
Dorsal calcaneocuboid ligament

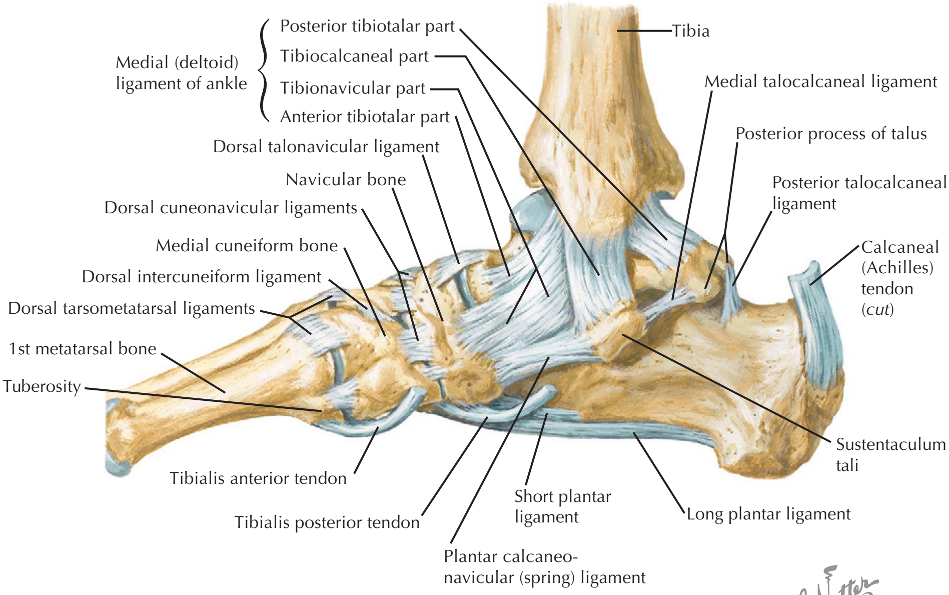

Anterior talofibular ligament
Medial malleolus
Lateral malleolus
Talus
Peroneal tendons
Achilles tendon

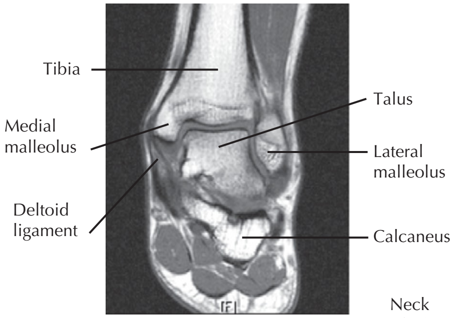
Ankle MRI, axial


Tibia
Fibula
Medial malleolus
Lateral malleolus
Talus
Calcaneofibular ligament
F

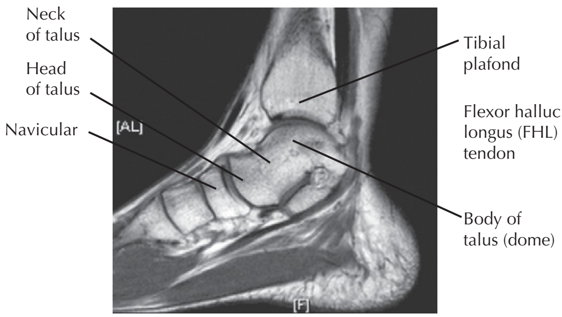
Ankle MRI, coronal

Right foot: medial view


Medial (deltoid) ligament of ankle
Posterior tibiotalar part
Tibiocalcaneal part
Tibionavicular part
Anterior tibiotalar part
Dorsal talonavicular ligament
Navicular bone
Dorsal cuneonavicular ligaments
Medial cuneiform bone
Dorsal intercuneiform ligament
Dorsal tarsometatarsal ligaments
1st metatarsal bone
Tuberosity
Tibialis anterior tendon
Tibialis posterior tendon
Plantar calcaneo-navicular (spring) ligament
Short plantar ligament
Long plantar ligament
Sustentaculum tali
Calcaneal (Achilles) tendon (*cut*)
Posterior talocalcaneal ligament
Posterior process of talus
Medial talocalcaneal ligament
Tibia

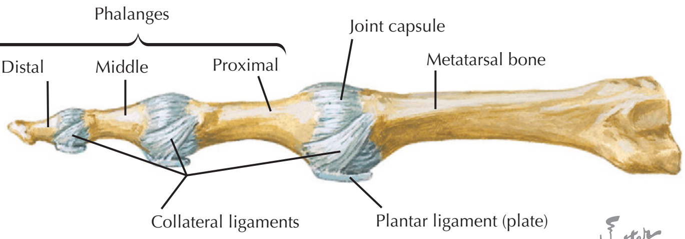

Tibia
Medial malleolus
Deltoid ligament
Talus
Lateral malleolus
Calcaneus
[F]

Ankle MRI, deltoid

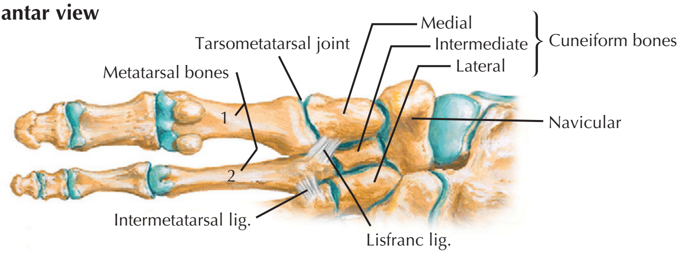

Neck of talus
Head of talus
Navicular
[AL]
Tibial plafond
Flexor hallucis longus (FHL) tendon
Body of talus (dome)
[F]

Ankle MRI, sagittal

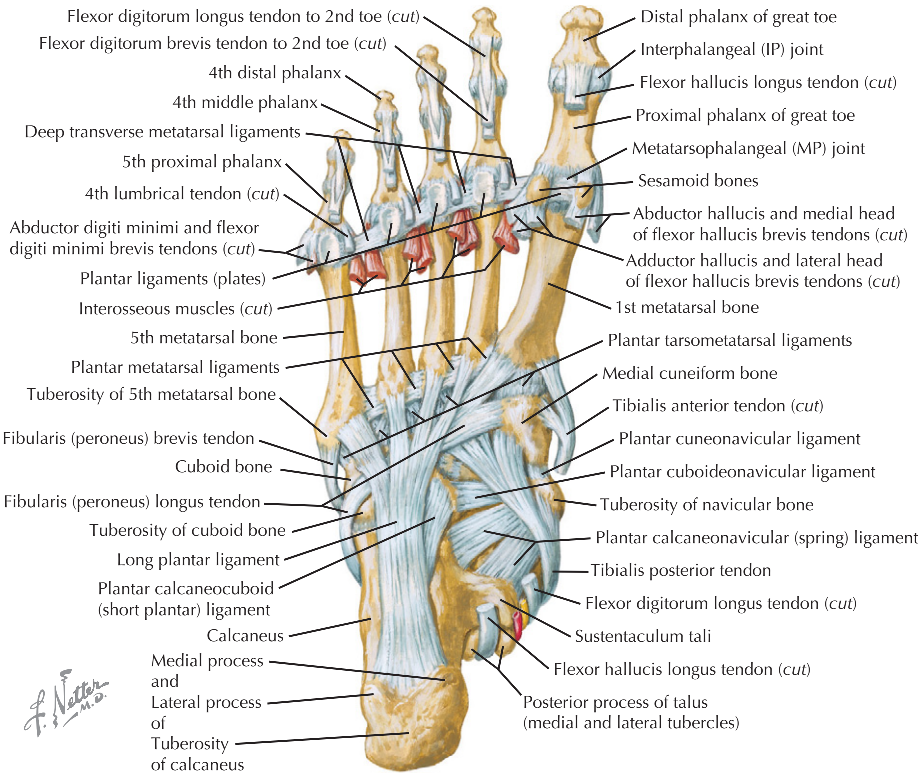
Capsules and ligaments of metatarsophalangeal and interphalangeal joints: lateral view



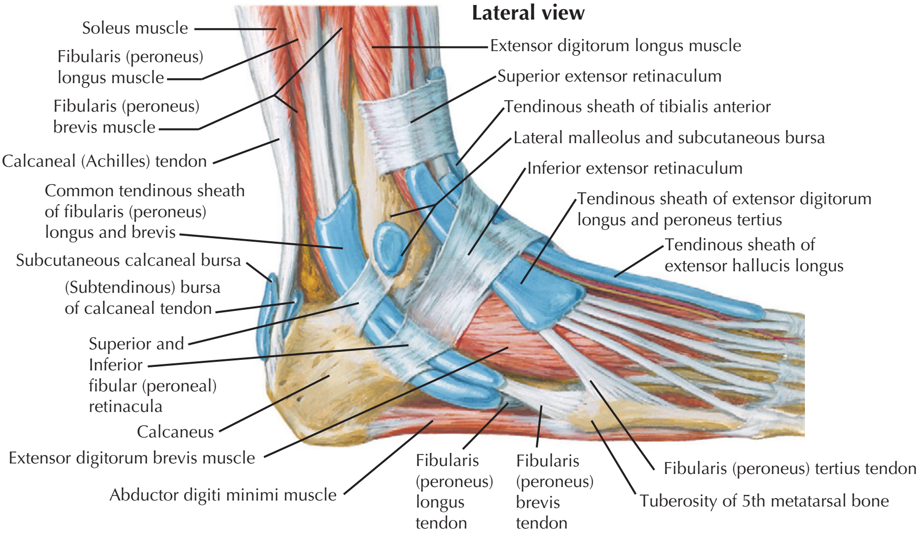
Plantar view



LIGAMENT		COMMENTS
INTERTARSAL		
Subtalar (Talocalcaneal)		
Articulation of 3 facets. Allows inversion/version (e.g., walking on uneven surfaces) as well as rotation.		
Extrinsic	• **Calcaneofibular**	• Primary support for subtalar joint. Also a main support for ankle joint.
Intrinsic	• **Interosseous talocalcaneal**	• Strong stabilizer in sinus tarsi. Injury can be cause of chronic instability.
	• **Cervical**	• Less stout secondary stabilizer. Also in sinus tarsi.
Capsular thickenings	• Medial talocalcaneal	• Medial tubercle to sustentaculum tali. Provides minimal support.
	• Lateral talocalcaneal	• Deep to calcaneofibular. Provides minimal support.
Other	• Inferior peroneal retinaculum	• Multiple insertions within sinus tarsi.
Dislocations: Closed reductions can be blocked by: EDB (medial dislocation) or PT tendon (lateral dislocation)		
Transverse Tarsal/Midtarsal (Chopart's)		
Two articulations: 1. talonavicular, 2. calcaneocuboid. **Motion:** abduction/adduction. **Function** depends on foot/subtalar position: **Eversion**—joints are parallel, permits motion (supple), occurs in early stance/"heel strike". **Inversion**—joints not parallel, no motion (stiff joint makes foot a rigid lever), occurs in late stance/"toe off."		
Talonavicular		
Highly congruent "ball & socket" type joint. Convex talar head in concave navicular ("acetabulum pedis")		
Plantar calcaneonavicular (Spring)		• Strong plantar support for talar head, from sustentaculum to navicular
Dorsal talonavicular		• Dorsal support
Calcaneonavicular		• Half of bifurcate ligament
Calcaneocuboid		
Calcaneocuboid		• Half of bifurcate ligament
Dorsal calcaneocuboid		• Dorsal support, minimal strength
Plantar calcaneocuboid (short plantar)		• Strong plantar support, from sustentaculum tali to plantar cuboid
Calcaneocuboid metatarsal (long plantar)		• Crosses multiple joints with multiple insertions
The tendon of the peroneus longus also crosses this joint and adds support.		
OTHER INTERTARSAL JOINTS		
Each of these joints has dorsal, plantar, and interosseous ligaments that bear the name of the corresponding joint.		
Cuboideonavicular Cuneonavicular Intercuneiform Cuneocuboid		• These joints are small, have very little motion or clinical significance. • The plantar ligaments are the strongest.

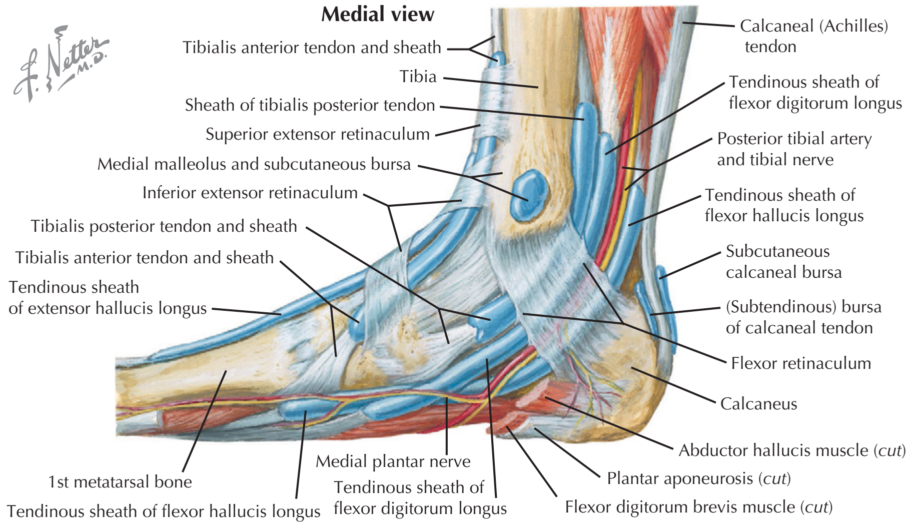

Flexor digitorum longus tendon to 2nd toe (*cut*)
Flexor digitorum brevis tendon to 2nd toe (*cut*)
4th distal phalanx
4th middle phalanx
Deep transverse metatarsal ligaments
5th proximal phalanx
4th lumbrical tendon (*cut*)
Abductor digiti minimi and flexor digiti minimi brevis tendons (*cut*)
Plantar ligaments (plates)
Interosseous muscles (*cut*)
5th metatarsal bone
Plantar metatarsal ligaments
Tuberosity of 5th metatarsal bone
Fibularis (peroneus) brevis tendon
Cuboid bone
Fibularis (peroneus) longus tendon
Tuberosity of cuboid bone
Long plantar ligament
Plantar calcaneocuboid (short plantar) ligament
Calcaneus
Medial process and Lateral process of Tuberosity of calcaneus
Distal phalanx of great toe
Interphalangeal (IP) joint
Flexor hallucis longus tendon (*cut*)
Proximal phalanx of great toe
Metatarsophalangeal (MP) joint
Sesamoid bones
Abductor hallucis and medial head of flexor hallucis brevis tendons (*cut*)
Adductor hallucis and lateral head of flexor hallucis brevis tendons (*cut*)
1st metatarsal bone
Plantar tarsometatarsal ligaments
Medial cuneiform bone
Tibialis anterior tendon (*cut*)
Plantar cuneonavicular ligament
Plantar cuboideonavicular ligament
Tuberosity of navicular bone
Plantar calcaneonavicular (spring) ligament
Tibialis posterior tendon
Flexor digitorum longus tendon (*cut*)
Sustentaculum tali
Flexor hallucis longus tendon (*cut*)
Posterior process of talus (medial and lateral tubercles)

LIGAMENTS	COMMENTS
OTHER JOINTS	
Tarsometatarsal (Lisfranc)	
Gliding joints. Make up the transverse arch of foot. 2nd MT base is the "keystone"	
Intermetatarsal Lisfranc: medial cuneiform to 2nd MT base Dorsal, plantar, interosseous tarsometatarsal	• B/w 2nd & 5th metatarsal bases. No ligament b/w 1st & 2nd MT • Primary stabilizer of articulation. Avulsion of ligament = "fleck" sign • Plantar ligaments are the strongest.
Metatarsophalangeal	
Condyloid joint	
Collateral Plantar plate	• Strong medial and lateral support; limits varus and valgus • Primary support. Loose origin on MT neck to strong insertion on P1 • Injured (avulsion from MT) in hyperextension injury/turf toe • Sesamoids adherent to plantar plate (within FHB tendon)
Deep transverse metatarsal	• B/w metatarsal heads. Can compress nerve = Morton's neuroma • The 1st/2nd ligament also attaches to and stabilizes lateral sesamoid
Intersesamoidal Abd. & add. hallucis tendons	• Runs between the two sesamoid bones, stabilizing them • Tendinous insertions on P1 add medial and lateral joint stability
Interphalangeal	
Hinge (ginglymus) joint	
Capsule Collateral and plantar plate	• Gives primary support • Additional support medial, lateral, and plantar



Lateral view

Soleus muscle
Fibularis (peroneus) longus muscle
Fibularis (peroneus) brevis muscle
Calcaneal (Achilles) tendon
Common tendinous sheath of fibularis (peroneus) longus and brevis
Subcutaneous calcaneal bursa
(Subtendinous) bursa of calcaneal tendon
Superior and Inferior fibular (peroneal) retinacula
Calcaneus
Extensor digitorum brevis muscle
Abductor digiti minimi muscle
Fibularis (peroneus) longus tendon
Fibularis (peroneus) brevis tendon
Extensor digitorum longus muscle
Superior extensor retinaculum
Tendinous sheath of tibialis anterior
Lateral malleolus and subcutaneous bursa
Inferior extensor retinaculum
Tendinous sheath of extensor digitorum longus and peroneus tertius
Tendinous sheath of extensor hallucis longus
Fibularis (peroneus) tertius tendon
Tuberosity of 5th metatarsal bone



Medial view

Tibialis anterior tendon and sheath
Tibia
Sheath of tibialis posterior tendon
Superior extensor retinaculum
Medial malleolus and subcutaneous bursa
Inferior extensor retinaculum
Tibialis posterior tendon and sheath
Tibialis anterior tendon and sheath
Tendinous sheath of extensor hallucis longus
1st metatarsal bone
Tendinous sheath of flexor hallucis longus
Medial plantar nerve
Tendinous sheath of flexor digitorum longus
Calcaneal (Achilles) tendon
Tendinous sheath of flexor digitorum longus
Posterior tibial artery and tibial nerve
Tendinous sheath of flexor hallucis longus
Subcutaneous calcaneal bursa
(Subtendinous) bursa of calcaneal tendon
Flexor retinaculum
Calcaneus
Abductor hallucis muscle (cut)
Plantar aponeurosis (cut)
Flexor digitorum brevis muscle (cut)
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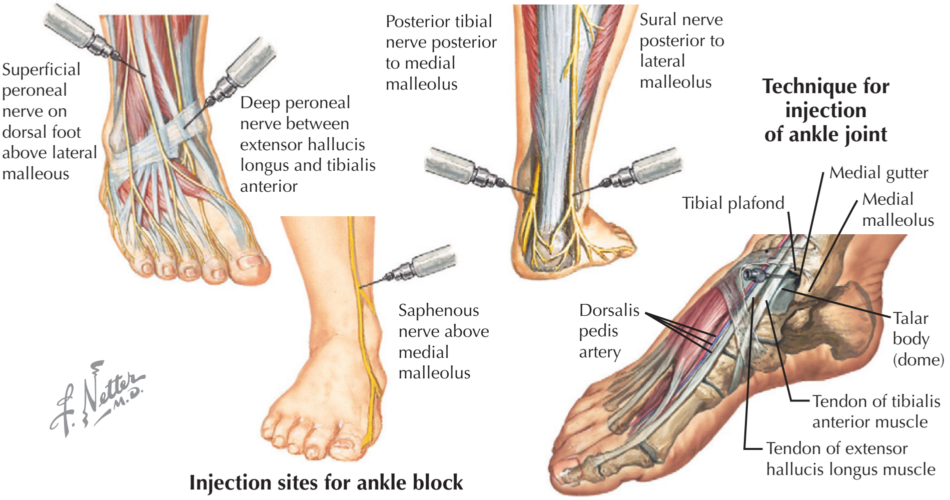
STRUCTURE	FUNCTION	COMMENT
Superior extensor retinaculum	Covers tendons, nerves, vessels of anterior compartment at ankle	Distal fibula to medial tibia
Inferior extensor retinaculum	Surrounds & covers tendons, etc. of anterior compartment in foot	"Y" shaped; calcaneus to medial malleolus and navicular
Flexor retinaculum	Covers tendons of posterior compartment	Medial malleolus to calcaneus; roof of tarsal tunnel
Superior & inferior peroneal retinaculum	Covers tendons & sheaths of lateral compartment at hind foot	Superior: lateral malleolus to calcaneus Inferior: inf. extensor retinaculum to calcaneus
Plantar aponeurosis (plantar fascia)	Supports longitudinal arch	Inflamed: plantar fasciitis; can develop nodules


Superficial peroneal nerve on dorsal foot above lateral malleous
Deep peroneal nerve between extensor hallucis longus and tibialis anterior
Posterior tibial nerve posterior to medial malleolus
Sural nerve posterior to lateral malleolus
Saphenous nerve above medial malleolus
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Tibial plafond
Medial gutter
Medial malleolus
Dorsalis pedis artery
Talar body (dome)
Tendon of tibialis anterior muscle
Tendon of extensor hallucis longus muscle

Injection sites for ankle block

Technique for injection of ankle joint

STEPS

ANKLE ARTHROCENTESIS

1. Ask patient about allergies
2. Plantarflex foot, palpate medial malleolus and sulcus between it and the tibialis anterior tendon.
3. Prep skin over ankle joint (iodine/antiseptic soap).
4. Anesthetize skin locally (quarter size spot).
5. Insert 20-gauge needle perpendicularly into the sulcus/ankle joint (medial to the tendon, inferior to distal tibia articular surface, lateral to medial malleolus). Gentle ankle distraction may assist in entering the joint. Aspirate fluid. If suspicious for infection, send fluid for gram stain and culture. Alternatively, may inject into the joint. The fluid should flow easily if needle is in joint.
6. Dress aspiration/injection site.

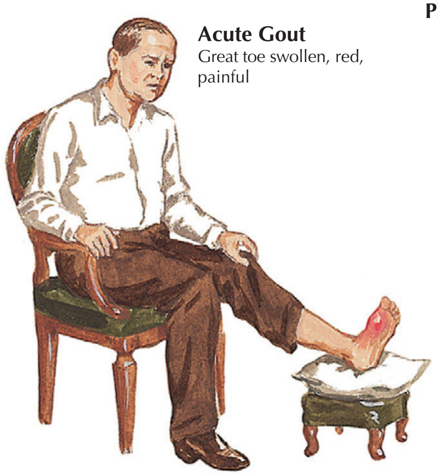
ANKLE BLOCK

Five separate nerves are blocked. Based on the necessary anesthesia, a complete or partial block can be performed.

1. Ask patient about allergies.
2. Prep skin (iodine/antiseptic soap) circumferentially around the ankle immediately above and below the malleoli.
3. Prepare syringe with 22- to 25-gauge needle with local anesthetic.
4. **Superficial peroneal nerve:** raise a wheal at least 3-4cm across anterolateral ankle from LM to midline.
5. **Deep peroneal nerve:** palpate TA and EHL tendons. Insert needle between tendons to bone, then withdraw slightly. Aspirate to ensure the needle is not in anterior tibial artery. Inject 2-3ml of local anesthetic.
6. **Saphenous nerve:** raise a wheal at least 2-3cm across the anteromedial ankle anterior to medial mall.
7. **Tibial nerve:** palpate posterior tibial artery pulse, FHL (if possible), and Achilles tendon behind the MM. Insert needle posterior to artery, anterior to FHL/Achilles tendon down to bone, then withdraw slightly. Aspirate to ensure the needle is not in the posterior tibial artery. Pull back from bone slightly and inject 2-3ml.
8. **Sural nerve:** raise a subcutaneous wheal at least 2-3cm across the posterolateral ankle b/w LM and Achilles tendon.
9. Dress each injection site.

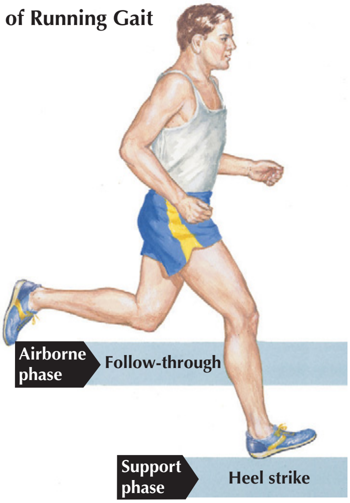
DIGITAL BLOCK

1. Ask patient about allergies.
2. Prep skin (iodine/soap) over the proximal dorsal toe and adjacent web space(s).
3. Prepare syringe with local without epinephrine and 25-gauge needle.
4. Insert needle along medial and lateral borders of the proximal phalanx to plantar surface. Aspirate to confirm needle is not in a vessel. Slowly inject as you withdraw the needle dorsally. 2-3ml of local should be adequate on either side. Raising a wheal dorsally across the proximal toe may improve the block.
5. Take care not to inject too much fluid into this closed space.
6. Dress the injection sites.



Acute Gout
Great toe swollen, red, painful

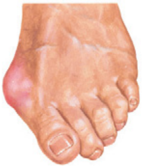
Phases of Running Gait



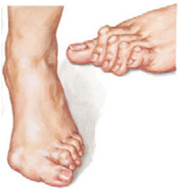
QUESTION	ANSWER	CLINICAL APPLICATION
1. Age	Young	Sprain, fractures
	Middle aged–elderly	Overuse injuries, arthritis, gout, hallux valgus, hammertoes
2. Pain		
a. Onset	Acute (less common)	Fracture, sprain, dislocation
	Chronic	Most foot/ankle disorders are chronic, runners
	After ankle sprain	Talar OCD, subluxating peroneal tendons or tendon tear, lateral process (talus) fracture, SPN injury
b. Location	Ankle	Fracture, osteoarthritis, instability, posterior tibial tendinitis
	Hind foot	Fracture, retrocalcaneal bursitis, Achilles tendinitis, arthritis
	Plantar foot	Plantar fasciitis, nerve compression, ulcer, metatarsalgia
	Midfoot	Osteoarthritis of the tarsus, fracture (Lisfranc), PTTD
	Forefoot	Fractures, metatarsalgia, Morton's neuroma, hammertoes
	1st MTPJ	Hallux vagus, hallux rigidus, sesamoiditis, fx, turf toe, gout
	Bilateral	Consider systemic illness, RA, CMT
c. Occurrence	Morning pain	Plantar fasciitis (improves with stretching)
	With activity	Overuse type injuries: stress fx, tendinitis, bursitis
3. Stiffness	Without locking	Ankle sprain, RA, osteoarthritis
	With locking	Loose body
4. Swelling	Yes	Fracture sprain, arthritis, gout
5. Trauma	Can bear weight	Sprain, contusion, minor fracture
	Cannot bear weight	Fracture: ankle, tarsal, metatarsal
	Fall	Calcaneus fracture, pilon fracture
6. Activity/occupation	Sports, repetitive motion	Achilles tendinitis, overuse injuries (e.g., stress fx)
	Standing all day	Overuse injuries: tendinitis, bursitis
7. Shoe type	Tight/narrow toe box	Hallux valgus (bunion most common in women)
8. Neurologic symptoms	Pain, numbness, tingling	Tarsal tunnel syndrome, diabetic neuropathy, other nerve compression
9. History of systemic disease	Manifestations in foot	Diabetes mellitus, gout, peripheral vascular disease, RA, Reiter's syndrome.

Anterior View

Bunion/Hallux Valgus

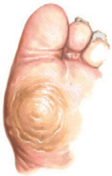


Hammertoe



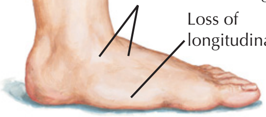
Plantar View

Callus



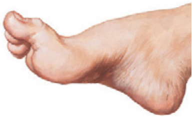
Medial View

Pes Planus



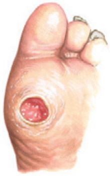
Medial view of pronated foot reveals flattened longitudinal arch

Cavovarus Foot



Plantar View

Ulcer



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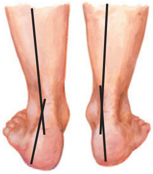
JOHN A.CRAIG MD
D. Mascaro

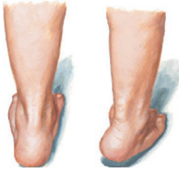
Posterior View

"Too many toes" sign



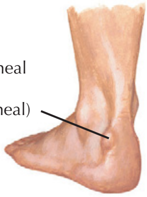
Posterior view reveals hyperpronation in left foot. In normal foot, midlines of calcaneus and leg are aligned or deviate less than 2°

Cavovarus Foot



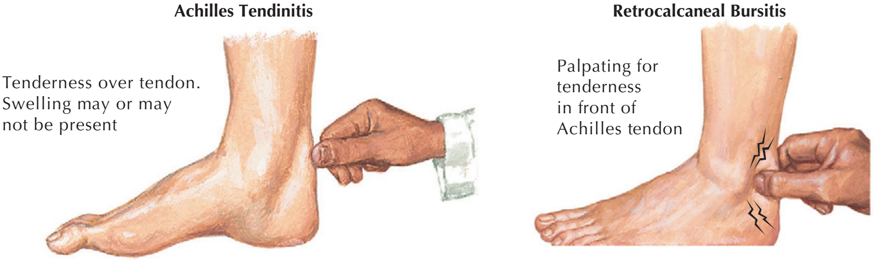
Posterior view clearly shows varus deformity of affected right foot.

Pump bump


Tender, slightly red nodule just lateral to calcaneal attachment of Achilles (calcaneal) tendon

EXAM	TECHNIQUE	CLINICAL APPLICATION/DDX
INSPECTION		
Foot (weight-bearing)	Anterior view Posterior view Medial view	Hallux valgus (bunion), hammertoes, other deformities (clubfeet, MT adductus) Slight valgus is normal; "pump-bump" seen with Achilles tendinitis Increased valgus: posterior tibialis dysfunction, tarsal coalition, planovalgus Varus alignment: neurologic disease (e.g., Charcot-Marie-Tooth) Pes planus (flat foot): posterior tibialis dysfunction, tarsal coalition, pediatric pes planovalgus Pes cavus (high arch): neurologic disease (e.g., Charcot-Marie-Tooth)
Foot (non-WB)	Plantar view	Ulcers (esp. in diabetics), callus, transfer lesions (callus under 2nd MT head)
Swelling	Ankle Foot: Dorsal Medial Diffuse	Sprain, fracture Fracture, contusion Posterior tibialis dysfunction Consider cardiovascular etiology
Skin	Color Hair	Pallor may indicate vascular disease; congestion may indicate venous insufficiency Decreased hair may indicate peripheral vascular disease
Shoes	Narrow toe box Abnormal wear	Associated with hallux valgus (esp. in women) May indicate malalignment (e.g., pes planus or cavus) or dysfunction (e.g., foot drop)

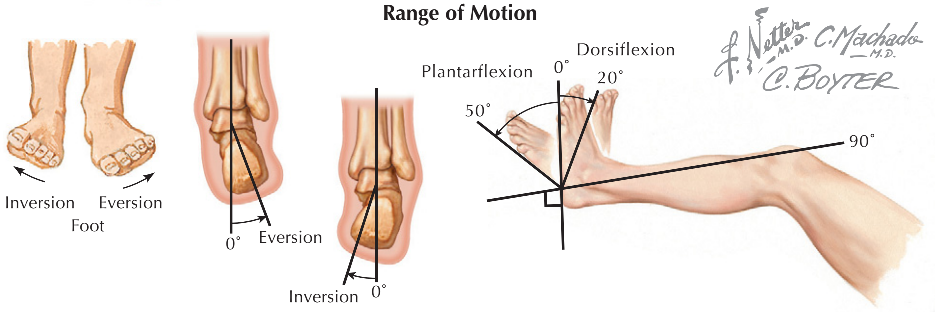
Palpation


Achilles Tendinitis

Retrocalcaneal Bursitis

Tenderness over tendon. Swelling may or may not be present
Palpating for tenderness in front of Achilles tendon

Range of Motion


Inversion
Eversion
Foot
0°
Eversion
Inversion
0°
Plantarflexion
0°
Dorsiflexion
20°
50°
90°
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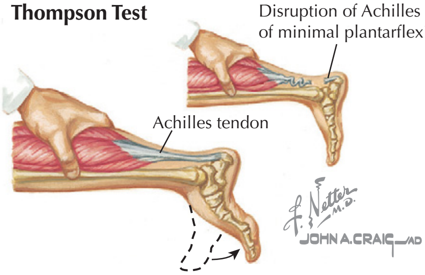
C.Machado M.D.
C. BOYTER

EXAM	TECHNIQUE	CLINICAL APPLICATION
PALPATION		
Bony structures	1st MP joint/MT& head	Bunion, pain: hallux rigidus, sesamoids, turf toe, gout
	Lesser MPT joint/MT	Pain: metatarsalgia, Freiberg's infraction, fx, tailor's bunion (5th MT head)
	Tarsal bones/midfoot	Tenderness suggests fracture, osteoarthritis, dislocation
	Calcaneus/heel	Pain: fracture; posterior: bursitis (pump bump); plantar: spur, plantar fasciitis; medial: nerve entrapment
	Malleoli	Pain indicates fracture, syndesmosis injury in leg
Soft tissue	Skin	Cool: peripheral vascular disease Swelling: trauma/infection vs venous insufficiency
	Between metatarsal heads	Pain: neuroma
	Medial ankle ligaments	Pain suggests ankle sprain (deltoid ligament)
	Tendons (at med. malleolus)	Pain indicates tendinitis, rupture
	Lateral ankle ligaments	Pain suggests ankle sprain (ATFL, CFL, PTFL [rare])
	Peroneal tendons (LM)	Pain indicates tendinitis, tear, dislocation/subluxation
	Achilles tendon	Pain: tendinitis; defect suggests Achilles rupture
RANGE OF MOTION		
Ankle: dorsiflex/plantarflex	Stabilize subtalar joint	Normal: flex 50°/extend 25°
Subtalar: inversion/eversion	Stabilize tibia	Normal: invert 5-10°/evert 5°
Transverse/midtarsal: adduction/abduction	Stabilize heel/hind foot, give abd./add. stress	Normal: adduct 20°/abduct 10°
Great toe:		
MTP: flex/extend	Stabilize foot, flex/extend	Normal: flex 75°/extend 75°; decreased in hallux rigidus
IP: flex/extend	Stabilize foot, flex/extend	Normal: flex 90°/extend 0°
Combine motions; Pronation: dorsiflexion, eversion, abduction; Supination: plantarflexion, inversion, adduction		

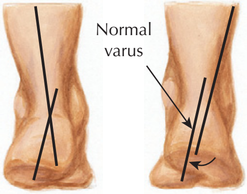
Thompson Test



Disruption of Achilles tendon results in absence of minimal plantarflexion of ankle when calf squeezed

Normal: Squeezing calf results in gastrocnemius and soleus contraction causing plantarflexion of ankle joint if Achilles tendon is intact

Heel Rise

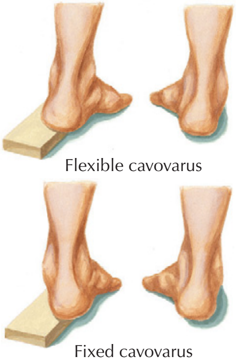


PTT dysfunction

Normal

On toe standing, normal PTT function pulls heel into varus. PTT dysfunction allows heel to remain in valgus poisition

Coleman Block Test

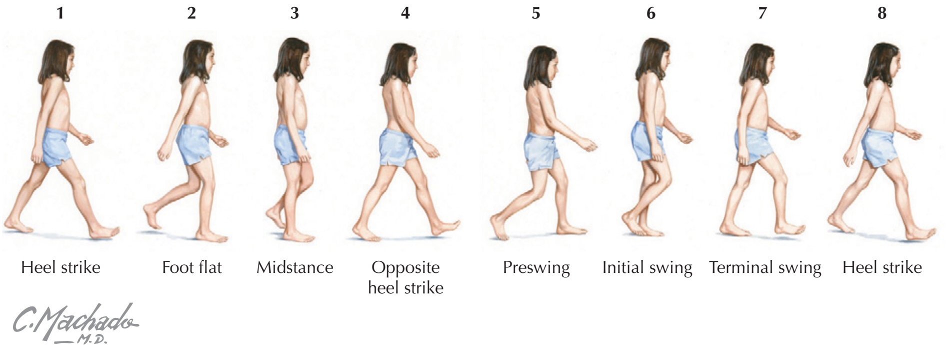


Flexible cavovarus

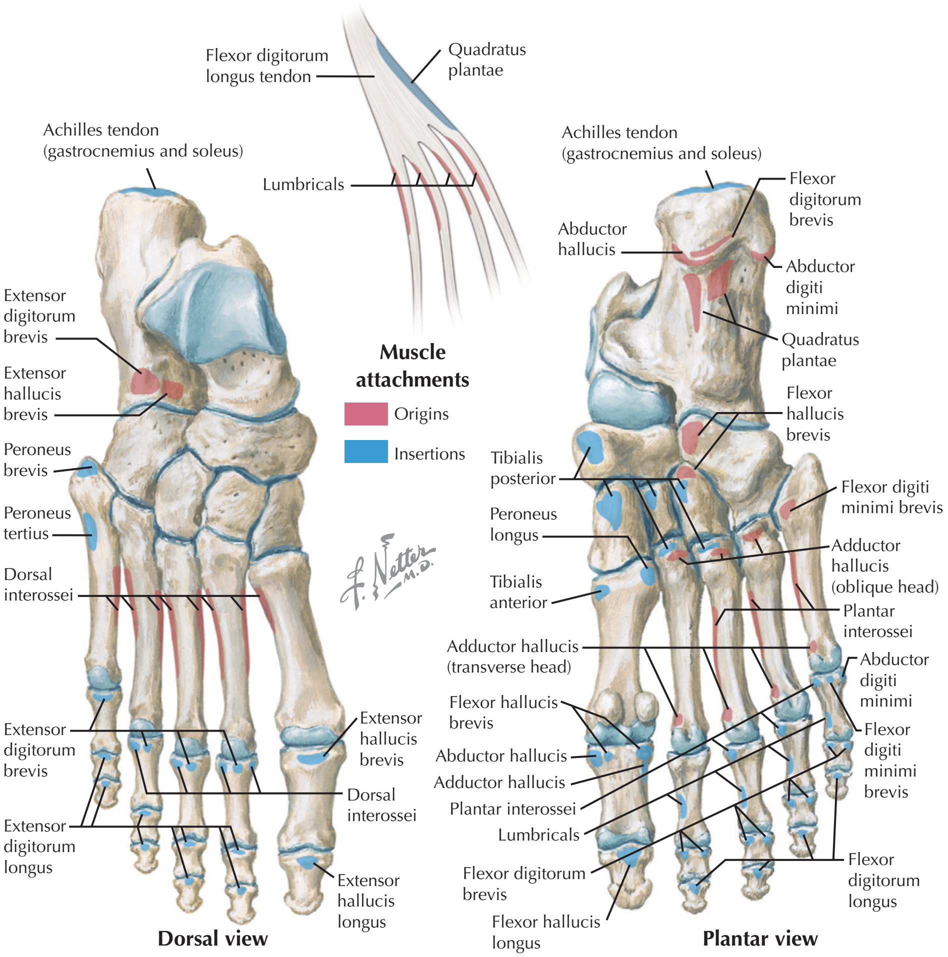
Fixed cavovarus

EXAM	TECHNIQUE	CLINICAL APPLICATION
	NEUROVASCULAR	
	Sensory	
Saphenous (L4)	Medial foot (med. cutaneous)	Deficit indicates corresponding nerve or root lesion
Tibial (L4-S1)	Plantar foot (med. & lat./plantar)	Deficit indicates corresponding nerve or root lesion
Superficial peroneal	Dorsal foot	Deficit indicates corresponding nerve or root lesion
Deep peroneal (L5)	1st dorsal web space	Deficit indicates corresponding nerve or root lesion
Sural (S1)	Lateral foot	Deficit indicates corresponding nerve or root lesion
	Motor	
Deep peroneal (L4)	Foot inversion/dorsiflexion	Weakness = tibialis anterior or corresponding nerve or root lesion
Deep peroneal (L5)	Great toe dorsiflex	Weakness = extensor hallucis longus or nerve or root lesion
Tibial (S1)	Foot plantarflexion	Weakness = gastrocnemius or nerve or root lesion
Superficial peroneal	Foot eversion	Weakness = peroneus muscles or nerve or root lesion
	Reflex	
S1	Achilles reflex	Hypoactive/absence indicates S1 radiculopathy
Upper motor neuron	Babinski reflex	Upgoing toes indicates an upper motor neuron disorder
Pulses	Dorsalis pedis (on dorsum) Post. tibial (post. med. mall.)	Decreased pulses = trauma/vascular compromise, peripheral vascular disease
	SPECIAL TESTS	
Thompson	Prone: squeeze calf	Absent foot plantarflexion indicates Achilles tendon rupture.
Anterior drawer	Stabilize tibia, PF foot, anterior force on heel	Tests lateral ligaments (esp. ATFL). Increased laxity indicates ligament injury.
Talar tilt	Stabilize tibia, DF foot, invert foot	Tests lateral ligaments (esp. CFL). Increased laxity indicates ligament injury.
Ext. rotation stress	Stabilize tibia, ER foot	Tests deep deltoid & syndesmotic ligs. Laxity indicates ligament injury
Eversion stress	Stabilize tibia, evert foot	Tests superficial deltoid ligament. Incr. laxity indicates ligament injury
Squeeze	Compress distal tibia/fibula	Pain may suggest a syndesmosis injury (sprain or complete rupture).
Heel rise	Standing, rise onto toes	Heel should go into varus. No varus in PTTD and fixed deformities. Inability to do single heel rise indicates PTTD.
Coleman block	Lateral foot and heel on block; 1st ray hangs free	Flexible hind foot varus: ankle will go into valgus or neutral when on block. Fixed hind foot varus: ankle will stay in varus on the block.
Tinel's sign	Tap nerve posterior to MM	Paresthesias/tingling indicate tibial nerve entrapment (in tarsal tunnel).
Compression	Squeeze foot at MT heads	Pain (or numbness/tingling): interdigital neuroma (Morton's neuroma)

Phases of gait



GAIT CYCLE
General
Complex interaction of multiple muscles and joints within both lower extremities to produce propulsion of the body
Definitions
Gait: the manner in which a person walks Step: from heel strike of one foot to heel strike of the opposite foot Stride: from heel strike of one foot to the subsequent heel strike of the same foot
Phases
Stance (62%): Part of gait when foot is in contact with ground. Can be subdivided into 3 (or 5) subcategories • Initial phase—double stance (12%): both feet in stance, opposite foot in toe off • Intermediate phase—single stance (38%): opposite foot in swing phase • Terminal phase—double stance (12%): both feet in stance, opposite foot in heel strike **Swing** (38%): Part of gait with foot in air, advancing forward
Sequence
1. Heel strike: Ankle is plantar flexed against the eccentrically contracting TA. The subtalar joint begins everting, allowing IR of tibia. 2. Foot flat: The gastrocnemius fires eccentrically to limit DF of ankle. The foot pronates and subtalar joint everts, resulting in a parallel and supple transverse tarsal joint, which allows the foot to accept the weight and accommodates for uneven surfaces. 3. Midstance: Body weight is over stance leg. The ankle is neutral. The foot begins to transition to a rigid position to allow for push off. 4. Heel off: The posterior tibialis (PT) initiates subtalar inversion (making the transverse tarsal joint unparallel and rigid). The foot supinates, the tibia externally rotates, and the gastrocnemius concentrically contracts producing plantarflexion of the ankle/heel off. 5. Toe off: The passive dorsiflexion of the toes initiates the windlass mechanism, which tightens the plantar fascia, deepening the arch and further inverting the subtalar joint, locking the transverse tarsal joint making the foot a rigid lever upon which to push off. 6. Preswing: the knee flexes to begin to give clearance for the swinging foot. 7. Midswing: knee and hip flexion as well as concentric anterior compartment (TA) contraction provide foot clearance 8. Terminal swing: The transition to heel strike begins


Flexor digitorum longus tendon
Quadratus plantae
Lumbricals
Achilles tendon (gastrocnemius and soleus)
Extensor digitorum brevis
Extensor hallucis brevis
Peroneus brevis
Peroneus tertius
Dorsal interossei
Extensor digitorum brevis
Extensor digitorum longus
Extensor hallucis brevis
Dorsal interossei
Extensor hallucis longus
Dorsal view
Muscle attachments
🟥 Origins
🟦 Insertions
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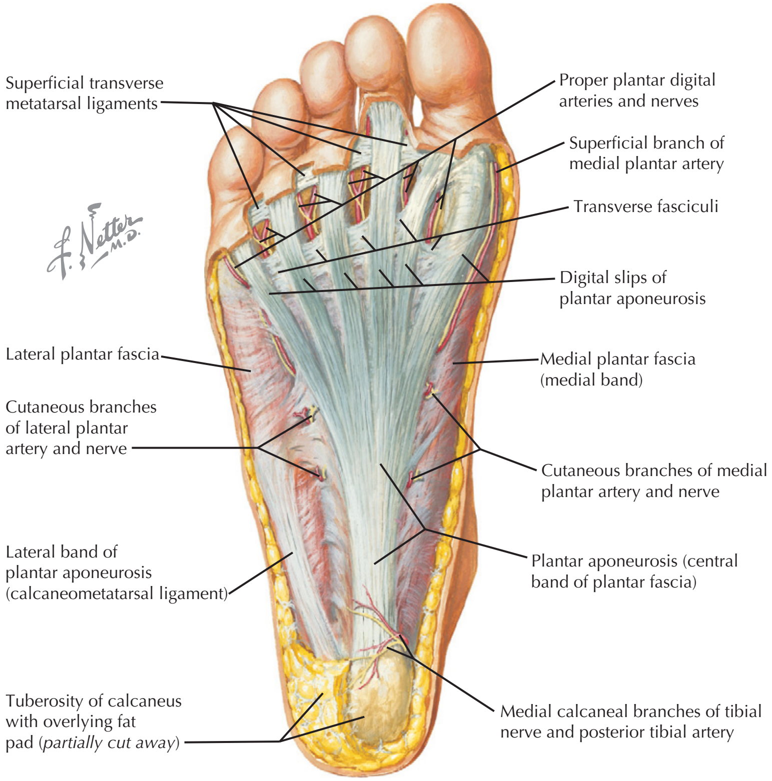
Achilles tendon (gastrocnemius and soleus)
Abductor hallucis
Flexor digitorum brevis
Abductor digiti minimi
Quadratus plantae
Flexor hallucis brevis
Tibialis posterior
Peroneus longus
Tibialis anterior
Flexor digiti minimi brevis
Adductor hallucis (oblique head)
Plantar interossei
Adductor hallucis (transverse head)
Abductor digiti minimi
Flexor hallucis brevis
Abductor hallucis
Adductor hallucis
Plantar interossei
Lumbricals
Flexor digiti minimi brevis
Flexor digitorum brevis
Flexor hallucis longus
Flexor digitorum longus
Plantar view

CALCANEUS	METATARSAL	PHALANGES—DORSAL	PHALANGES—PLANTAR	FDL TENDON
Dorsal Extensor hallucis brevis Extensor digitorum brevis **Plantar** Flexor digitorum brevis Abductor hallucis Abductor digiti minimi **Posterior** Gastrocnemius/soleus (Achilles tendon)	**Dorsal** Peroneus brevis Peroneus tertius Dorsal interosseous **Plantar** Tibialis anterior Peroneus longus Adductor hallucis (oblique head) Flexor digiti minimi brevis Plantar interosseous Adductor hallucis (transverse head)	Extensor hallucis brevis Extensor hallucis longus Extensor digitorum brevis Extensor digitorum longus Dorsal interosseous	Adductor hallucis (transverse head) Abductor hallucis Flexor hallucis brevis Adductor hallucis Flexor hallucis longus Flexor digitorum brevis Flexor digitorum longus Flexor digiti minimi brevis Abductor digiti minimi Lumbricals Plantar interosseous	Lumbrical Quadratus plantae


Superficial transverse metatarsal ligaments
Proper plantar digital arteries and nerves
Superficial branch of medial plantar artery
Transverse fasciculi
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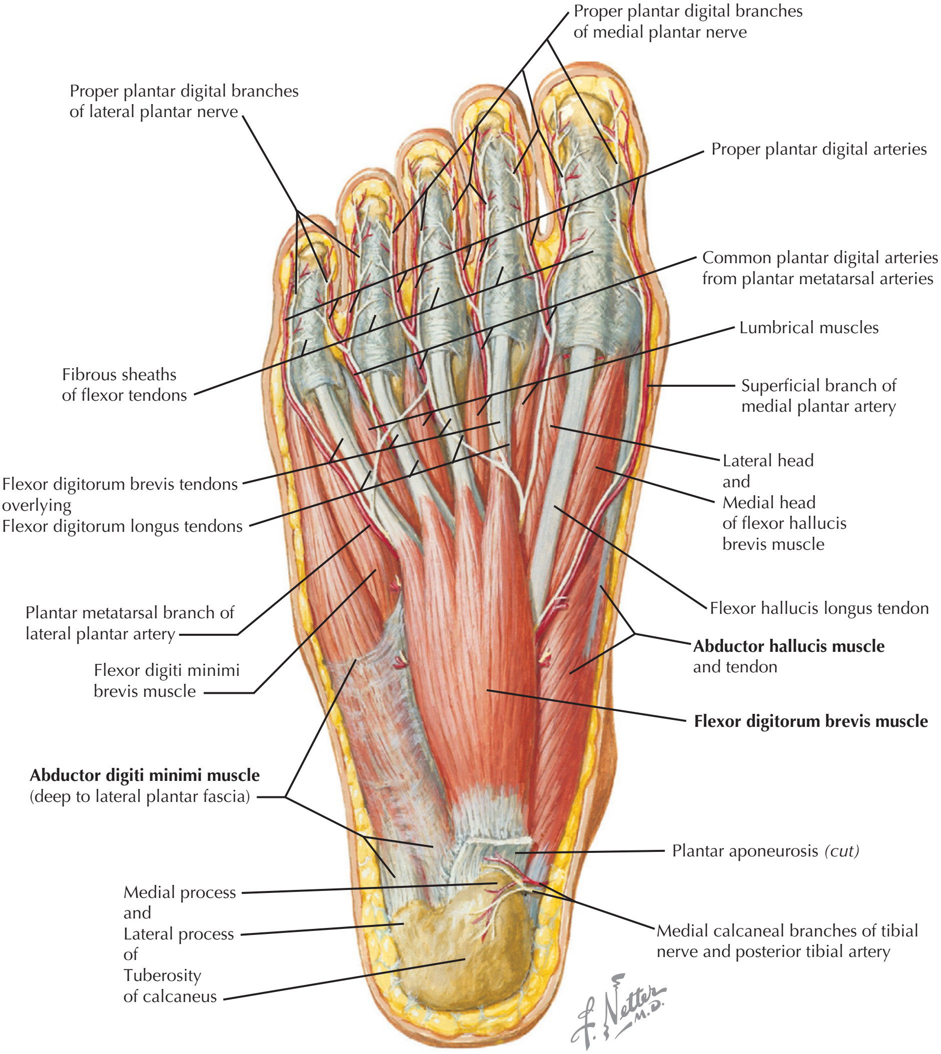
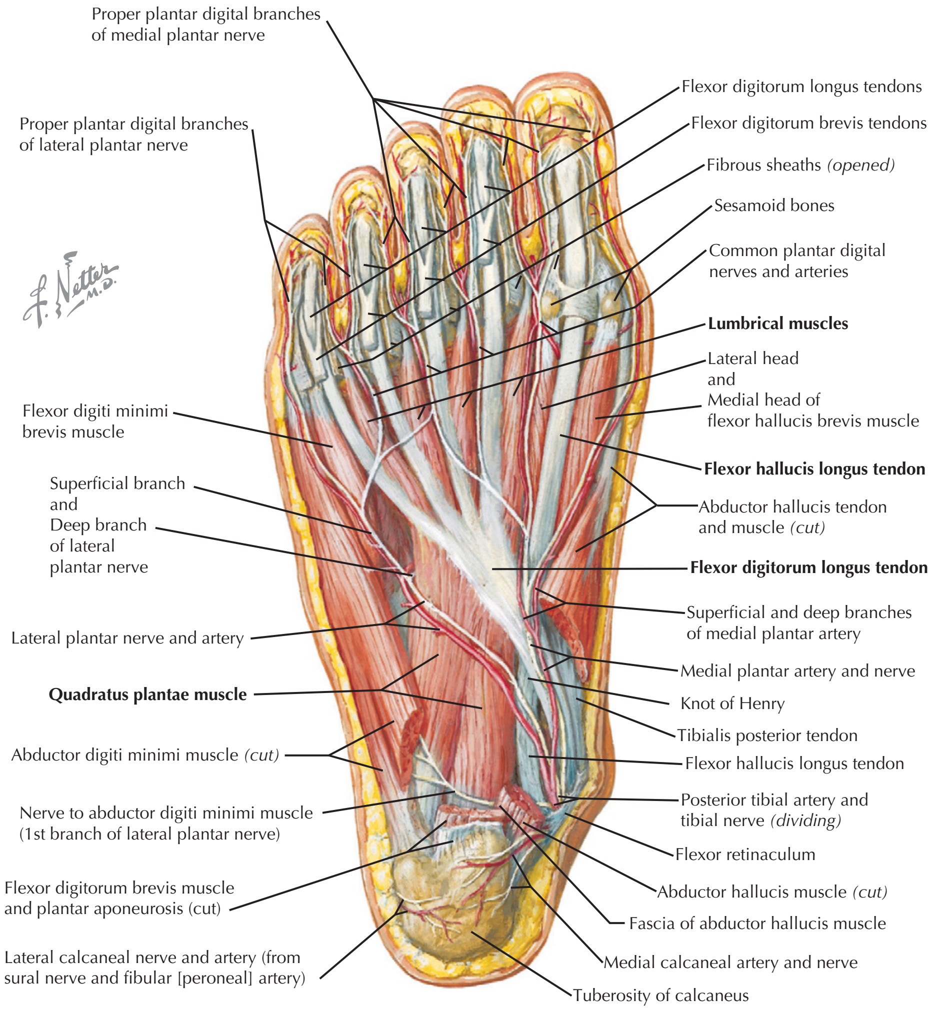
Digital slips of plantar aponeurosis
Lateral plantar fascia
Medial plantar fascia (medial band)
Cutaneous branches of lateral plantar artery and nerve
Cutaneous branches of medial plantar artery and nerve
Lateral band of plantar aponeurosis (calcaneometatarsal ligament)
Plantar aponeurosis (central band of plantar fascia)
Tuberosity of calcaneus with overlying fat pad (*partially cut away*)
Medial calcaneal branches of tibial nerve and posterior tibial artery

STRUCTURE/FUNCTION	COMMENT
PLANTAR FASCIA	
Structure: 3 portions	Disorders affecting the fascia include plantar fasciitis and fibromatosis
1. Central band (considered the plantar aponeurosis)	Thick single band runs from calcaneus and fans out and divides distally to insert on each toe From medial calcaneal tuberosity to: Superficial—flexor tendon sheaths Deep—deep transverse metatarsal ligaments
2. Medial band	Supports the abductor hallucis muscle
3. Lateral band	Supports the abductor digiti minimi muscle Inserts on the base of 5th metatarsal. Can be cause of avulsion fracture
Function 1. Stabilizes longitudinal arch 2. Protects underlying structures 3. Stabilizes foot in gait via the windlass mechanism	

LAYER	STRUCTURES
LAYERS OF THE FOOT	
Plantar fascia	3 bands—see above
1: 3 muscles	Abductor hallucis, flexor digitorum brevis, abductor digiti minimi
2: 2 muscles	Quadratus plantae, lumbricals (2 tendons: FHL and FDL)
3: 3 muscles	Flexor hallucis brevis, adductor hallucis, flexor digiti minimi brevis
4: 2 muscles	Plantar interossei, dorsal interossei (2 tendons: PL and PT)

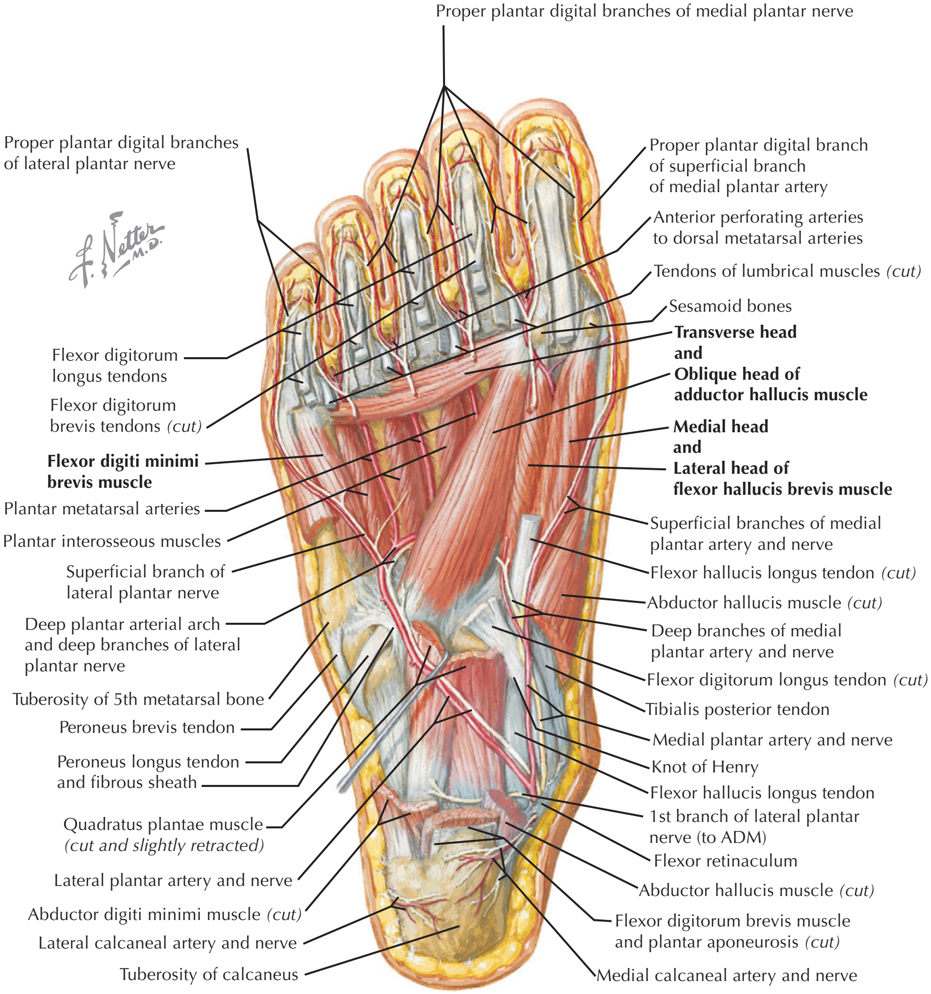

Proper plantar digital branches of medial plantar nerve
Proper plantar digital branches of lateral plantar nerve
Proper plantar digital arteries
Common plantar digital arteries from plantar metatarsal arteries
Lumbrical muscles
Fibrous sheaths of flexor tendons
Superficial branch of medial plantar artery
Lateral head and Medial head of flexor hallucis brevis muscle
Flexor digitorum brevis tendons overlying Flexor digitorum longus tendons
Flexor hallucis longus tendon
Plantar metatarsal branch of lateral plantar artery
Abductor hallucis muscle and tendon
Flexor digiti minimi brevis muscle
Flexor digitorum brevis muscle
Abductor digiti minimi muscle (deep to lateral plantar fascia)
Plantar aponeurosis (cut)
Medial process and Lateral process of Tuberosity of calcaneus
Medial calcaneal branches of tibial nerve and posterior tibial artery

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
		FIRST LAYER			
Abductor hallucis	Calcaneal tuberosity, medial process	Through med. sesamoid to proximal phalanx of great toe	Medial plantar	Abducts great toe	Fascia can entrap nerve to ADM
Flexor digitorum brevis (FDB)	Calcaneal tuberosity, medial process	Sides of middle phalanges: lateral 4 toes	Medial plantar	Flexes lateral 4 toes	Supports longitudinal arch
Abductor digiti minimi (ADM)	Calcaneal tuberosity, medial & lateral processes	Lateral base of proximal phalanx: 5th toe	Lateral plantar (1st branch)	Abducts small toe	Nerve can be entrapped by abd. h. fascia


Proper plantar digital branches of medial plantar nerve
Proper plantar digital branches of lateral plantar nerve
Flexor digiti minimi brevis muscle
Superficial branch and Deep branch of lateral plantar nerve
Lateral plantar nerve and artery
Quadratus plantae muscle
Abductor digiti minimi muscle (cut)
Nerve to abductor digiti minimi muscle (1st branch of lateral plantar nerve)
Flexor digitorum brevis muscle and plantar aponeurosis (cut)
Lateral calcaneal nerve and artery (from sural nerve and fibular [peroneal] artery)
Flexor digitorum longus tendons
Flexor digitorum brevis tendons
Fibrous sheaths (opened)
Sesamoid bones
Common plantar digital nerves and arteries
Lumbrical muscles
Lateral head and Medial head of flexor hallucis brevis muscle
Flexor hallucis longus tendon
Abductor hallucis tendon and muscle (cut)
Flexor digitorum longus tendon
Superficial and deep branches of medial plantar artery
Medial plantar artery and nerve
Knot of Henry
Tibialis posterior tendon
Flexor hallucis longus tendon
Posterior tibial artery and tibial nerve (dividing)
Flexor retinaculum
Abductor hallucis muscle (cut)
Fascia of abductor hallucis muscle
Medial calcaneal artery and nerve
Tuberosity of calcaneus

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
SECOND LAYER					
Quadratus plantae	Medial and lateral plantar calcaneus	Lateral FDL tendon	Lateral plantar	Assists FDL with toe flexion	Two heads/bellies join on FDL tendon
Lumbricals	Separate FDL tendons	Proximal phalanges, extensor expansion	1: medial plantar 2-4: lateral plantar	Flex MTP joint, extend IP joint	1st lumbrical attaches to only 1 FDL tendon

- Medial and lateral plantar nerves are terminal branches of the tibial nerve; they run in the 2nd layer.
- Tendons of FHL and FDL also pass through in the second layer.
- FHL tendon courses between tubercles of posterior process of talus, under sustentaculum tali, then deep to FDL at knot of Henry (crossing of FHL & FDL).


Proper plantar digital branches of medial plantar nerve
Proper plantar digital branches of lateral plantar nerve
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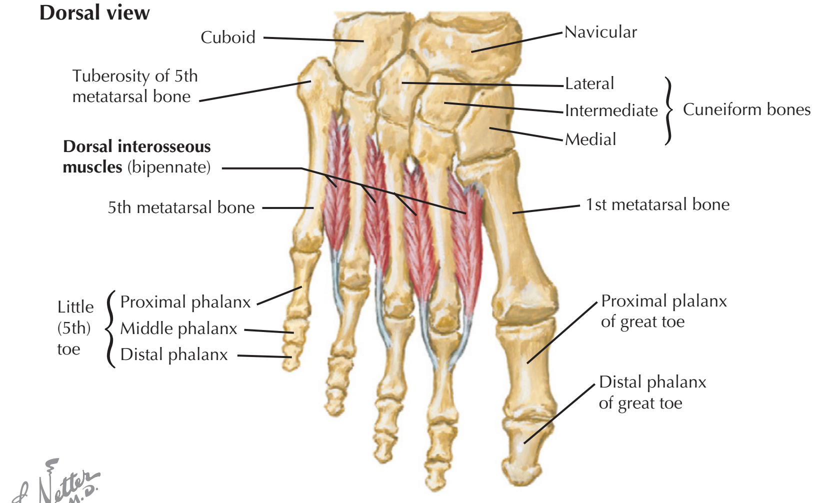
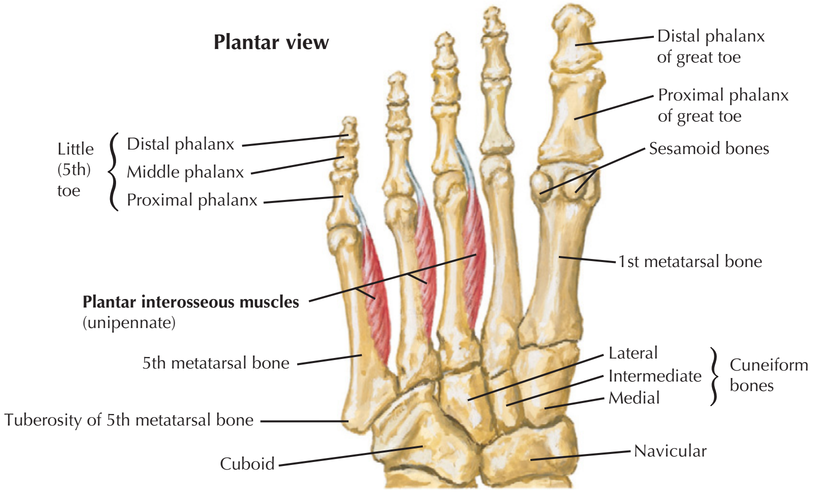
Flexor digitorum longus tendons
Flexor digitorum brevis tendons *(cut)*
Flexor digiti minimi brevis muscle
Plantar metatarsal arteries
Plantar interosseous muscles
Superficial branch of lateral plantar nerve
Deep plantar arterial arch and deep branches of lateral plantar nerve
Tuberosity of 5th metatarsal bone
Peroneus brevis tendon
Peroneus longus tendon and fibrous sheath
Quadratus plantae muscle *(cut and slightly retracted)*
Lateral plantar artery and nerve
Abductor digiti minimi muscle *(cut)*
Lateral calcaneal artery and nerve
Tuberosity of calcaneus
Proper plantar digital branch of superficial branch of medial plantar artery
Anterior perforating arteries to dorsal metatarsal arteries
Tendons of lumbrical muscles *(cut)*
Sesamoid bones
Transverse head and Oblique head of adductor hallucis muscle
Medial head and Lateral head of flexor hallucis brevis muscle
Superficial branches of medial plantar artery and nerve
Flexor hallucis longus tendon *(cut)*
Abductor hallucis muscle *(cut)*
Deep branches of medial plantar artery and nerve
Flexor digitorum longus tendon *(cut)*
Tibialis posterior tendon
Medial plantar artery and nerve
Knot of Henry
Flexor hallucis longus tendon
1st branch of lateral plantar nerve (to ADM)
Flexor retinaculum
Abductor hallucis muscle *(cut)*
Flexor digitorum brevis muscle and plantar aponeurosis *(cut)*
Medial calcaneal artery and nerve

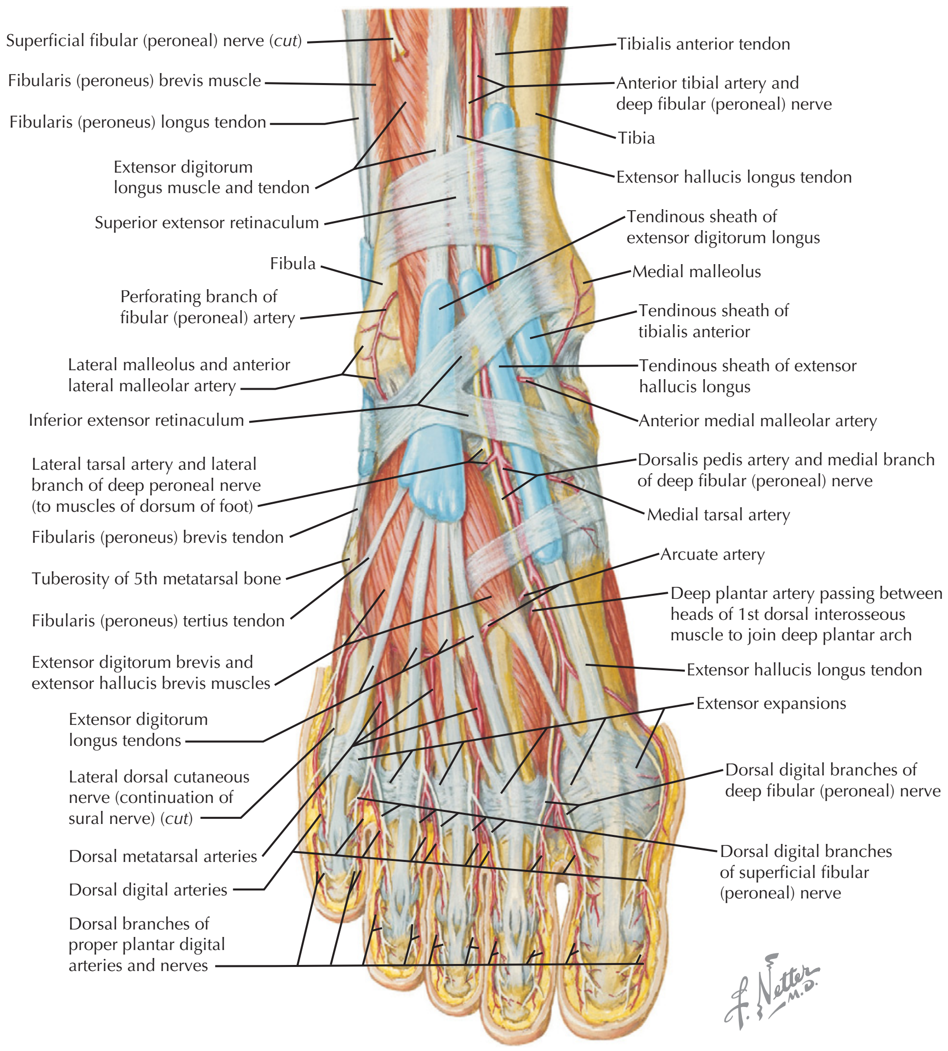
MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
THIRD LAYER					
Flexor hallucis brevis (FHB)	Cuboid, lateral cuneiform	Through sesamoids to proximal phalanx of great toe	Medial plantar	Assists great toe flexion at MTPJ	Sesamoid bones are within the tendons
Adductor hallucis	Oblique: base 2-4 MT Transverse: lateral 4 MTP	Through lateral sesamoid to lateral proximal phalanx of great toe	Lateral plantar	Adducts great toe	2 heads have different orientations; contributes to hallux valgus deformity
Flexor digiti minimi brevis (FDMB)	Base of 5th metatarsal	Base of proximal phalanx of small toe	Lateral plantar	Flex small toe	Small, relatively insignificant muscle


Dorsal view
Cuboid
Tuberosity of 5th metatarsal bone
Dorsal interosseous muscles (bipennate)
5th metatarsal bone
Little (5th) toe
Proximal phalanx
Middle phalanx
Distal phalanx
Navicular
Lateral
Intermediate
Medial
Cuneiform bones
1st metatarsal bone
Proximal plalanx of great toe
Distal phalanx of great toe


Plantar view
Little (5th) toe
Distal phalanx
Middle phalanx
Proximal phalanx
Plantar interosseous muscles (unipennate)
5th metatarsal bone
Tuberosity of 5th metatarsal bone
Cuboid
Distal phalanx of great toe
Proximal phalanx of great toe
Sesamoid bones
1st metatarsal bone
Lateral
Intermediate
Medial
Cuneiform bones
Navicular

MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
FOURTH LAYER					
Plantar interossei (3)	Medial 3rd, 4th, 5th MTs	Medial proximal phalanges: toes 3-5	Lateral plantar	Adduct toes, flex MTPJ; extend LPJ	Attachment to MT is medial for all 3
Dorsal interossei (4)	Adjacent MT shafts	Medial proximal phalanx (2nd toe) Lateral proximal phalanx (toes 2-4)	Lateral plantar	Abduct toes	Larger than the plantar interossei (bipennate)

Peroneus longus and tibialis posterior tendons pass through the fourth layer.
PAD = Plantar ADduct, DAB = Dorsal ABduct (the 2nd digit is reference point for abduction/adduction in the foot).


Superficial fibular (peroneal) nerve (*cut*)
Fibularis (peroneus) brevis muscle
Fibularis (peroneus) longus tendon
Extensor digitorum longus muscle and tendon
Superior extensor retinaculum
Fibula
Perforating branch of fibular (peroneal) artery
Lateral malleolus and anterior lateral malleolar artery
Inferior extensor retinaculum
Lateral tarsal artery and lateral branch of deep peroneal nerve (to muscles of dorsum of foot)
Fibularis (peroneus) brevis tendon
Tuberosity of 5th metatarsal bone
Fibularis (peroneus) tertius tendon
Extensor digitorum brevis and extensor hallucis brevis muscles
Extensor digitorum longus tendons
Lateral dorsal cutaneous nerve (continuation of sural nerve) (*cut*)
Dorsal metatarsal arteries
Dorsal digital arteries
Dorsal branches of proper plantar digital arteries and nerves
Tibialis anterior tendon
Anterior tibial artery and deep fibular (peroneal) nerve
Tibia
Extensor hallucis longus tendon
Tendinous sheath of extensor digitorum longus
Medial malleolus
Tendinous sheath of tibialis anterior
Tendinous sheath of extensor hallucis longus
Anterior medial malleolar artery
Dorsalis pedis artery and medial branch of deep fibular (peroneal) nerve
Medial tarsal artery
Arcuate artery
Deep plantar artery passing between heads of 1st dorsal interosseous muscle to join deep plantar arch
Extensor hallucis longus tendon
Extensor expansions
Dorsal digital branches of deep fibular (peroneal) nerve
Dorsal digital branches of superficial fibular (peroneal) nerve
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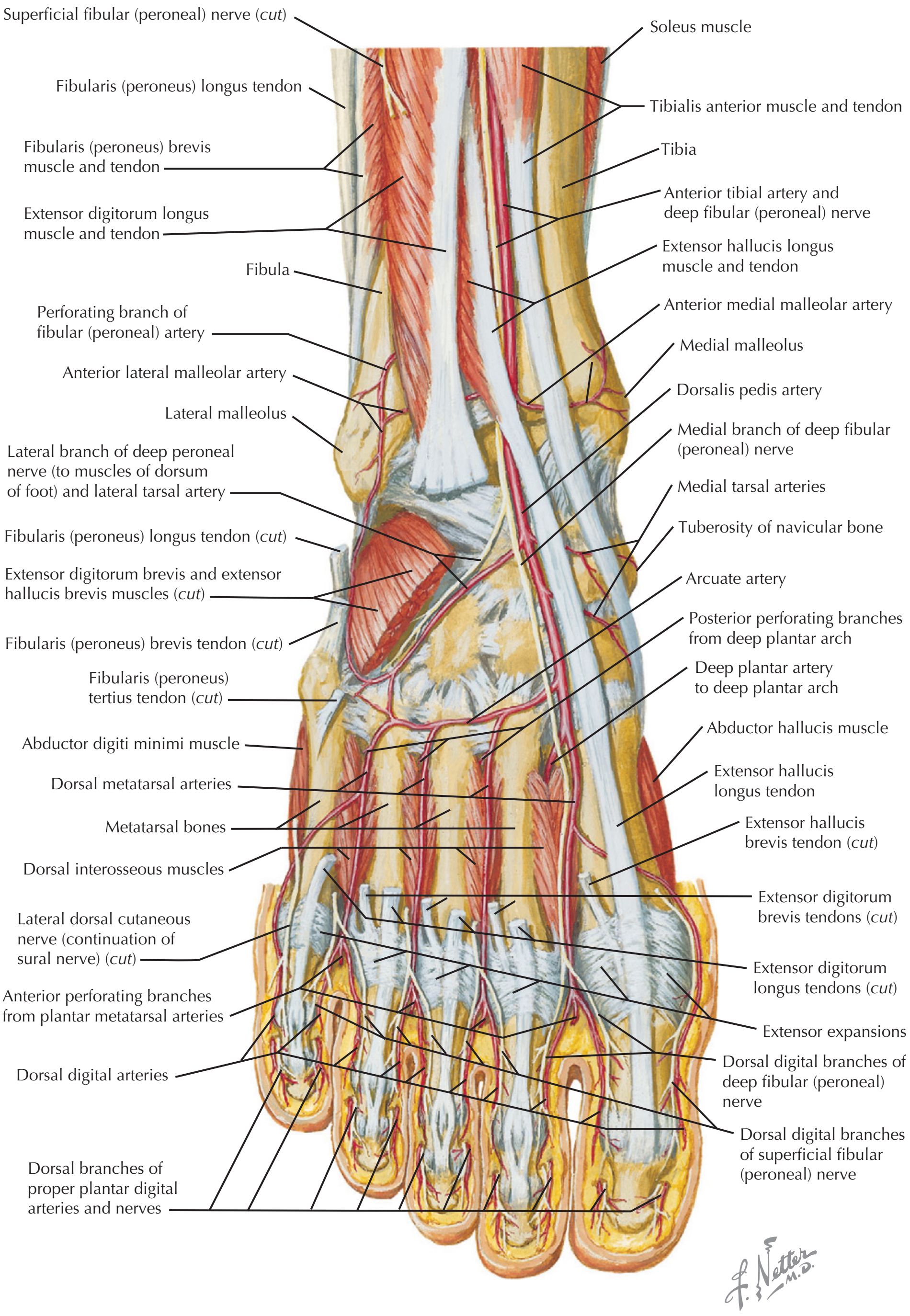
MUSCLE	ORIGIN	INSERTION	NERVE	ACTION	COMMENT
DORSUM					
Extensor hallucis brevis (EHB)	Dorsolateral calcaneus	Base of proximal phalanx of great toe	Deep peroneal	Extends great toe at MCPJ	Assists EHL with its action
Extensor digitorum brevis (EDB)	Dorsolateral calcaneus	Base of proximal phalanx: toes 2-4	Deep peroneal	Extends lesser toes at MCPJ	No tendon to small toe


Superficial fibular (peroneal) nerve (*cut*)
Fibularis (peroneus) longus tendon
Fibularis (peroneus) brevis muscle and tendon
Extensor digitorum longus muscle and tendon
Fibula
Perforating branch of fibular (peroneal) artery
Anterior lateral malleolar artery
Lateral malleolus
Lateral branch of deep peroneal nerve (to muscles of dorsum of foot) and lateral tarsal artery
Fibularis (peroneus) longus tendon (*cut*)
Extensor digitorum brevis and extensor hallucis brevis muscles (*cut*)
Fibularis (peroneus) brevis tendon (*cut*)
Fibularis (peroneus) tertius tendon (*cut*)
Abductor digiti minimi muscle
Dorsal metatarsal arteries
Metatarsal bones
Dorsal interosseous muscles
Lateral dorsal cutaneous nerve (continuation of sural nerve) (*cut*)
Anterior perforating branches from plantar metatarsal arteries
Dorsal digital arteries
Dorsal branches of proper plantar digital arteries and nerves
Soleus muscle
Tibialis anterior muscle and tendon
Tibia
Anterior tibial artery and deep fibular (peroneal) nerve
Extensor hallucis longus muscle and tendon
Anterior medial malleolar artery
Medial malleolus
Dorsalis pedis artery
Medial branch of deep fibular (peroneal) nerve
Medial tarsal arteries
Tuberosity of navicular bone
Arcuate artery
Posterior perforating branches from deep plantar arch
Deep plantar artery to deep plantar arch
Abductor hallucis muscle
Extensor hallucis longus tendon
Extensor hallucis brevis tendon (*cut*)
Extensor digitorum brevis tendons (*cut*)
Extensor digitorum longus tendons (*cut*)
Extensor expansions
Dorsal digital branches of deep fibular (peroneal) nerve
Dorsal digital branches of superficial fibular (peroneal) nerve
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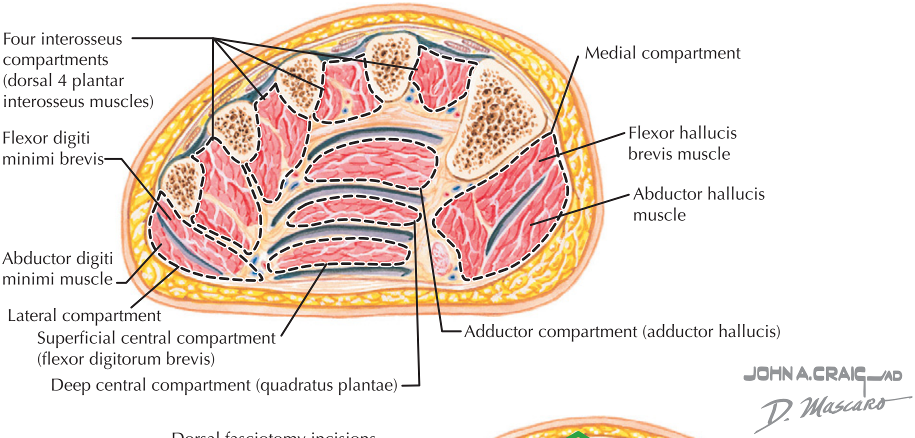
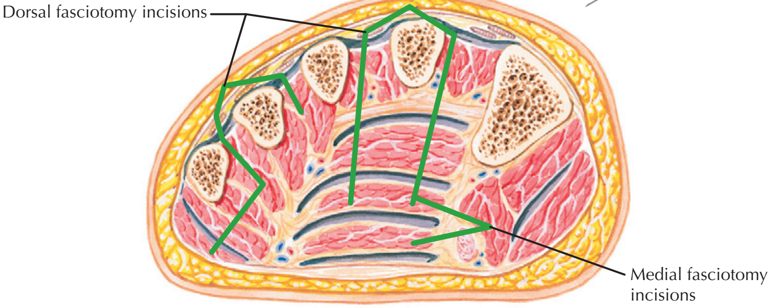
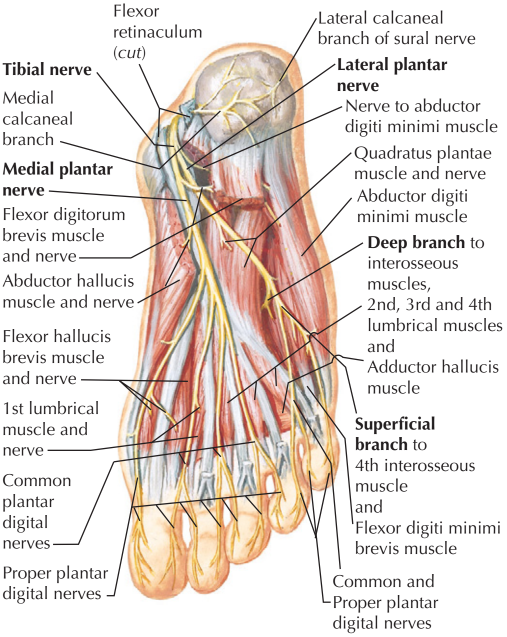

Four interosseus compartments (dorsal 4 plantar interosseus muscles)
Flexor digiti minimi brevis
Abductor digiti minimi muscle
Lateral compartment
Superficial central compartment (flexor digitorum brevis)
Deep central compartment (quadratus plantae)
Medial compartment
Flexor hallucis brevis muscle
Abductor hallucis muscle
Adductor compartment (adductor hallucis)
JOHN A.CRAIG_AD
D. Mascaro

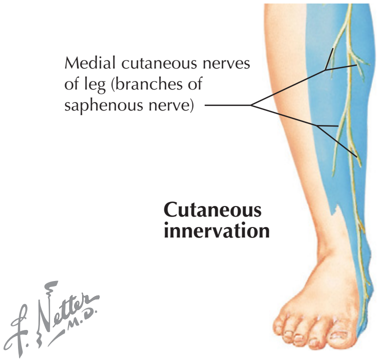

Dorsal fasciotomy incisions
Medial fasciotomy incisions

COMPARTMENT	CONTENTS
COMPARTMENTS (9)	
Medial	Abductor hallucis, flexor hallucis brevis, FHL tendon
Lateral	Abductor digiti minimi, flexor digiti minimi
Superficial central	Flexor digitorum brevis, lumbricals (4), FDL tendons
Deep central (calcaneal)	Quadratus plantae, posterior tibial neurovascular bundle
Adductor	Adductor hallucis
Interosseous (1-2)	Dorsal interosseous muscle
Interosseous (2-3)	Dorsal and plantar interosseous muscles
Interosseous (3-4)	Dorsal and plantar interosseous muscles
Interosseous (4-5)	Dorsal and plantar interosseous muscles
Deep central (calcaneal) compartment communicates with the deep posterior compartment of the leg.	
FASCIOTOMIES	
Incisions	3 incisions (2 dorsal and 1 medial) can release all compartments.
Dorsal (1)	Over 2nd metatarsal, dissect on both sides: release medial 2 interosseous, adductor, deep central
Dorsal (2)	Over 4th metatarsal, dissect on both sides: release lateral 2 interosseous, lateral, and both central
Medial	Along medial border of hind foot & midfoot: release medial, superficial, and deep central compartments

Cutaneous innervation of sole


Flexor retinaculum (*cut*)
Tibial nerve
Medial calcaneal branch
Medial plantar nerve
Flexor digitorum brevis muscle and nerve
Abductor hallucis muscle and nerve
Flexor hallucis brevis muscle and nerve
1st lumbrical muscle and nerve
Common plantar digital nerves
Proper plantar digital nerves
Lateral calcaneal branch of sural nerve
Lateral plantar nerve
Nerve to abductor digiti minimi muscle
Quadratus plantae muscle and nerve
Abductor digiti minimi muscle
Deep branch to interosseous muscles, 2nd, 3rd and 4th lumbrical muscles and Adductor hallucis muscle
Superficial branch to 4th interosseous muscle and Flexor digiti minimi brevis muscle
Common and Proper plantar digital nerves

LUMBAR PLEXUS
Posterior Division
Saphenous (L2-4): Branch of femoral nerve, descends in superficial medial leg then anterior to medial malleolus to medial arch of foot. *Sensory:* Medial ankle and foot (arch) *Motor:* None
SACRAL PLEXUS
Anterior Division
Tibial (L4-S3): Posterior to medial malleolus, into tarsal tunnel, divides on plantar surface into **medial** and **lateral plantar nerves.** *Sensory:* Medial heel, via **medial calcaneal nerve** *Motor:* None (before dividing)
Medial plantar: Runs medially in foot within the 2nd plantar layer. Compression can cause medial foot/arch pain (esp. in runners). *Sensory:* Medial plantar foot and toes *Motor:* • First plantar layer ◦ Abductor hallucis ◦ Flexor digitorum brevis (FDB) • Second plantar layer ◦ Lumbricals (medial 2) • Third plantar layer ◦ Flexor hallucis brevis (FHB)
Lateral plantar: Gives branch to ADM (can be entrapped by abductor hallucis fascia), then runs laterally within the 2nd plantar layer. *Sensory:* Lateral plantar foot and toes *Motor:* • First plantar layer ◦ Abductor digiti minimi (ADM): via **1st branch** (Baxter's n.) • Second plantar layer ◦ Quadratus plantae ◦ Lumbricals (lateral 2) • Third plantar layer ◦ Adductor hallucis ◦ Flexor digiti minimi brevis • Fourth plantar layer ◦ Dorsal interosseous ◦ Plantar interosseous


Medial cutaneous nerves of leg (branches of saphenous nerve)
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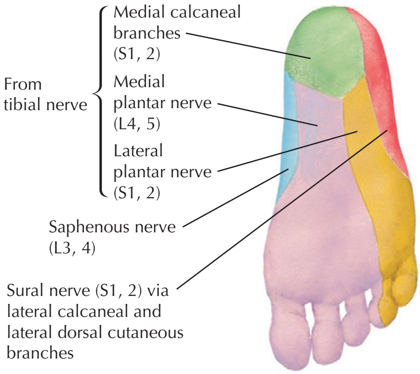
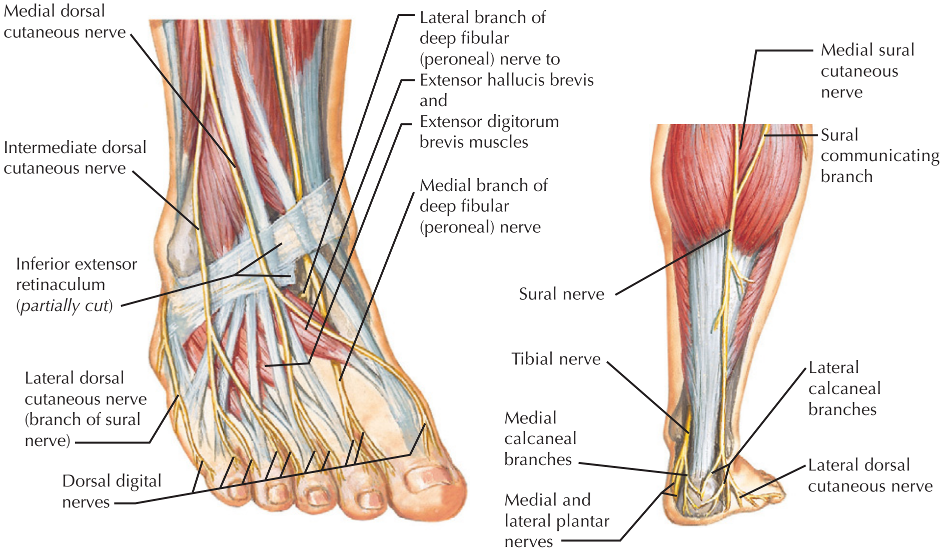
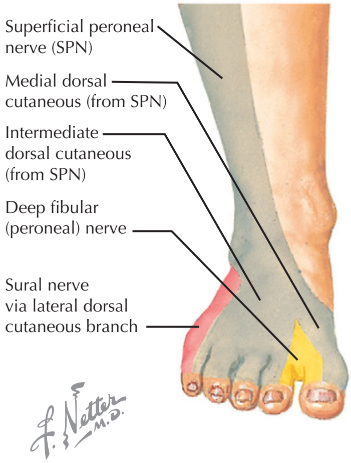
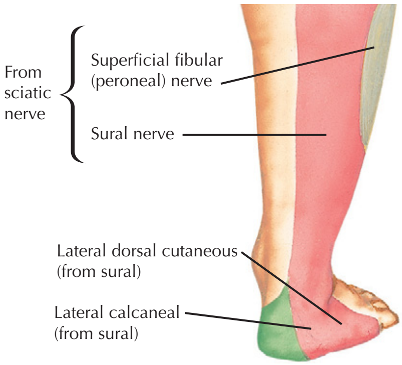
Cutaneous innervation

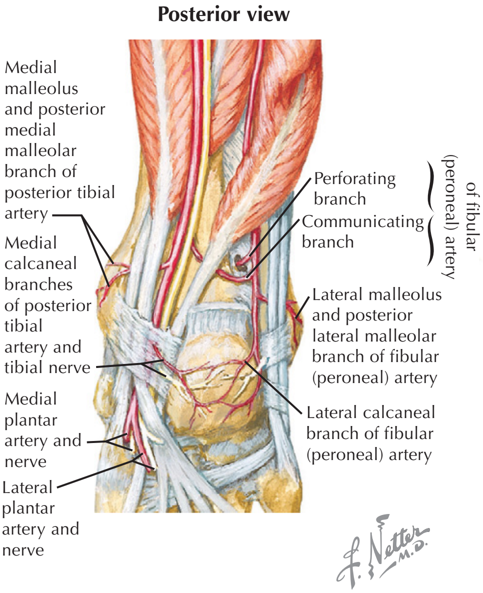

From tibial nerve
Medial calcaneal branches (S1, 2)
Medial plantar nerve (L4, 5)
Lateral plantar nerve (S1, 2)
Saphenous nerve (L3, 4)
Sural nerve (S1, 2) via lateral calcaneal and lateral dorsal cutaneous branches

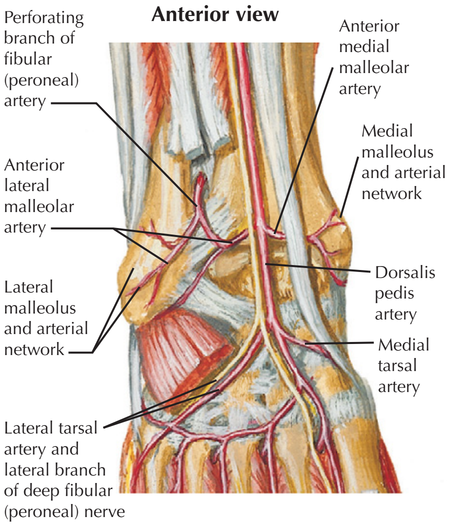

Medial dorsal cutaneous nerve
Intermediate dorsal cutaneous nerve
Inferior extensor retinaculum (*partially cut*)
Lateral dorsal cutaneous nerve (branch of sural nerve)
Dorsal digital nerves
Lateral branch of deep fibular (peroneal) nerve to Extensor hallucis brevis and Extensor digitorum brevis muscles
Medial branch of deep fibular (peroneal) nerve
Medial sural cutaneous nerve
Sural communicating branch
Sural nerve
Tibial nerve
Medial calcaneal branches
Medial and lateral plantar nerves
Lateral calcaneal branches
Lateral dorsal cutaneous nerve


Superficial peroneal nerve (SPN)
Medial dorsal cutaneous (from SPN)
Intermediate dorsal cutaneous (from SPN)
Deep fibular (peroneal) nerve
Sural nerve via lateral dorsal cutaneous branch
F. Netter M.D.


From sciatic nerve
Superficial fibular (peroneal) nerve
Sural nerve
Lateral dorsal cutaneous (from sural)
Lateral calcaneal (from sural)

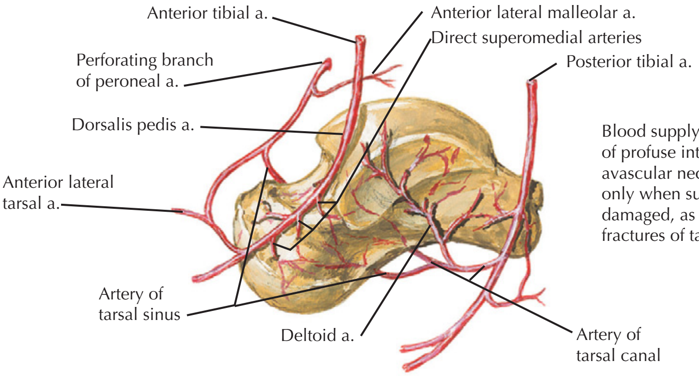
SACRAL PLEXUS
Posterior Division
Deep peroneal: Runs in anterior compartment of leg with anterior tibial artery, under inferior extensor retinaculum (can entrap nerve), then divides into motor (lateral) and sensory (medial) branches. *Sensory:* 1st/2nd toe interdigital space via **medial** branch *Motor:* Via **lateral** branch ◦ Extensor hallucis brevis (EHB) ◦ Extensor digitorum brevis (EDB)
Superficial peroneal: Runs in lateral compartment of leg, crosses anteriorly 12cm above LM to dorsal foot, then divides into 2 nerves. Can be injured during ORIF of ankle or by anterolateral arthroscopy portal. *Sensory:* Dorsal foot: **intermediate dorsal cutaneous n.** Medial hallux: via **medial dorsal cutaneous** nerve *Motor:* None (in foot and ankle)
Other
Sural: Formed from medial sural cutaneous (tibial nerve) and lateral sural cutaneous (peroneal nerve), runs subcutaneously in posterolateral leg. Gives a branch to the heel, then terminates in lateral foot and toes. *Sensory:* Lateral heel: via **lateral calcaneal nerve** Lateral foot: via **lateral dorsal cutaneous** nerve *Motor:* None
Dorsal foot sensory innervation: 3 cutaneous nerves (2 from superficial peroneal nerve, 1 from sural nerve)


Posterior view
Medial malleolus and posterior medial malleolar branch of posterior tibial artery
Medial calcaneal branches of posterior tibial artery and tibial nerve
Medial plantar artery and nerve
Lateral plantar artery and nerve
Perforating branch
Communicating branch
of fibular (peroneal) artery
Lateral malleolus and posterior lateral malleolar branch of fibular (peroneal) artery
Lateral calcaneal branch of fibular (peroneal) artery


Anterior view
Perforating branch of fibular (peroneal) artery
Anterior lateral malleolar artery
Lateral malleolus and arterial network
Lateral tarsal artery and lateral branch of deep fibular (peroneal) nerve
Anterior medial malleolar artery
Medial malleolus and arterial network
Dorsalis pedis artery
Medial tarsal artery

ARTERY	COURSE	BRANCHES	COMMENT/SUPPLY
ANTERIOR TIBIAL ARTERY			
Anterior medial malleolar	Under TA & EHL tendons to medial malleolus	None	Supplies medial malleolus
Anterior lateral malleolar	Under EDL tendon to lateral malleolus	None	Supplies lateral malleolus
Dorsalis pedis	Along dorsum of foot with deep peroneal nerve	Continuation of anterior tibial artery in foot	Supplies dorsum of foot via multiple branches (see foot table)
POSTERIOR TIBIAL ARTERY			
Posterior medial malleolar	Under PT and FDL tendons to medial malleolus	None	Supplies medial malleolus
Medial calcaneal	With med. calcaneal nerve (tibial)	None	Supplies heel/calcaneus
Terminal Branches			
Lateral plantar	Between quadratus plantae & FDB in 2nd layer w/lateral plantar n.	Deep plantar arch	Larger of the terminal branches Terminates as deep plantar arch
Medial plantar	Between abductor hallucis and FDB in 2nd layer with medial plantar nerve	Superficial branch 1 proper plantar digital Deep branch	Runs in medial foot Supplies medial plantar hallux Supplies central plantar midfoot
PERONEAL ARTERY			
Perforating artery	Pierces interosseous membrane going to anterior ankle	Branches or contributes to tarsal sinus artery	Joins with ant. lat. malleolus a. Direct supply to posterior talus
Posterior lateral malleolar	Under PL and PB tendons to lateral malleolus	None	Supplies lateral malleolus
Lateral calcaneal	With lat. calcaneal nerve (sural)	None	Supplies heel/calcaneus
Ant. & post. medial malleolar arteries & ant. & post. lateral malleolar arteries form an anastomosis at each malleolus.			

Blood Supply of Talus


Anterior tibial a.
Anterior lateral malleolar a.
Direct superomedial arteries
Posterior tibial a.
Perforating branch of peroneal a.
Dorsalis pedis a.
Anterior lateral tarsal a.
Artery of tarsal sinus
Deltoid a.
Artery of tarsal canal
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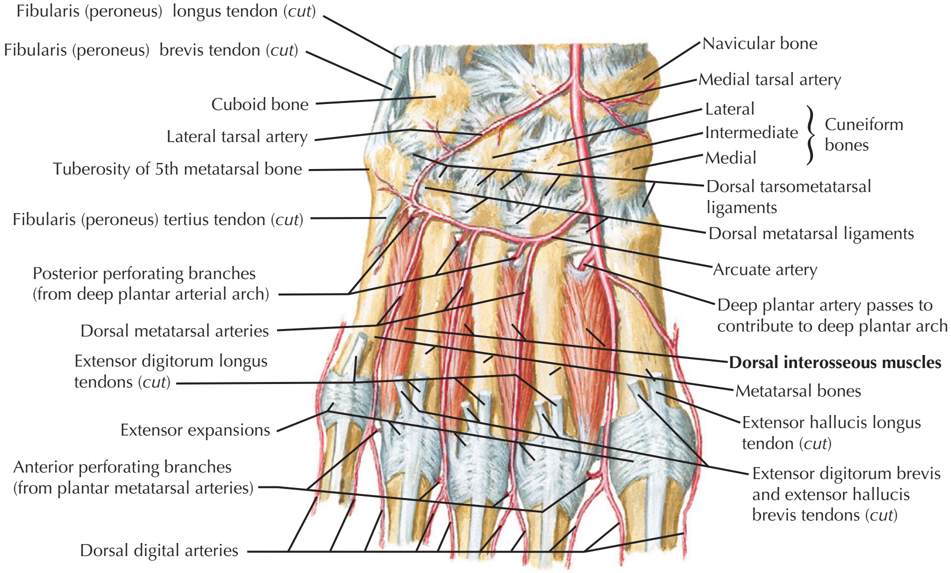
Blood supply of talus. Because of profuse intraosseous anastomoses, avascular necrosis commonly occurs only when surrounding soft tissue is damaged, as in types II and III fractures of talar neck

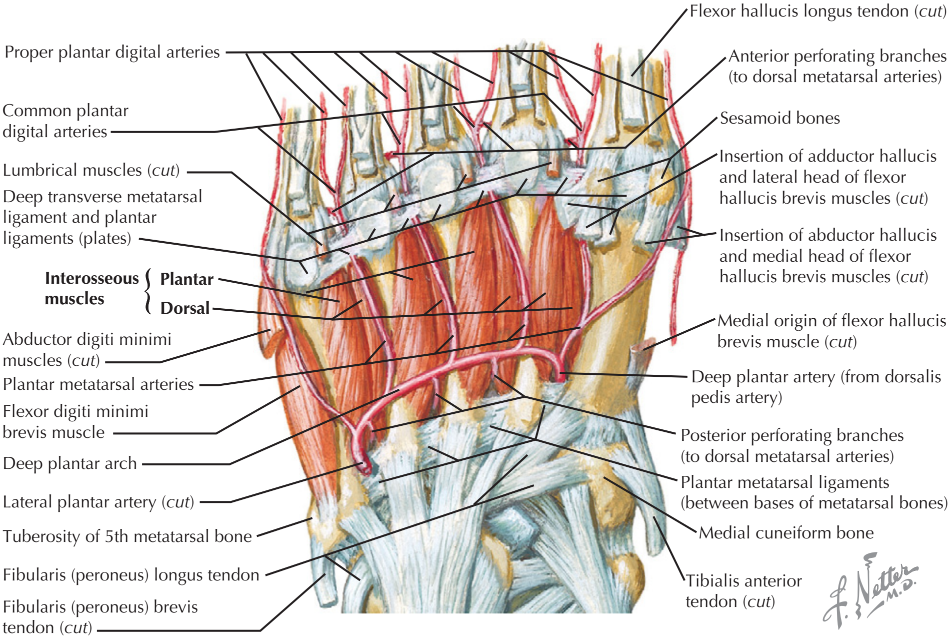
Dorsal view


Fibularis (peroneus) longus tendon (*cut*)
Fibularis (peroneus) brevis tendon (*cut*)
Cuboid bone
Lateral tarsal artery
Tuberosity of 5th metatarsal bone
Fibularis (peroneus) tertius tendon (*cut*)
Posterior perforating branches (from deep plantar arterial arch)
Dorsal metatarsal arteries
Extensor digitorum longus tendons (*cut*)
Extensor expansions
Anterior perforating branches (from plantar metatarsal arteries)
Dorsal digital arteries
Navicular bone
Medial tarsal artery
Lateral
Intermediate
Medial
Cuneiform bones
Dorsal tarsometatarsal ligaments
Dorsal metatarsal ligaments
Arcuate artery
Deep plantar artery passes to contribute to deep plantar arch
Dorsal interosseous muscles
Metatarsal bones
Extensor hallucis longus tendon (*cut*)
Extensor digitorum brevis and extensor hallucis brevis tendons (*cut*)

ARTERY	STEM ARTERY	BONE SUPPLIED
BLOOD SUPPLY OF TALUS		
1. Artery of tarsal canal	Posterior tibial (PT)	Body (dome): primary supply of body
2. Deltoid artery	Artery of tarsal canal (or PT)	Medial body; artery pierces deltoid ligament
3. Direct superomedial arteries	Dorsalis pedis	Head and neck
4. Artery of tarsal sinus	Dorsalis pedis and/or Peroneal (perforating br.)	Neck and lateral body, also contributes to head
5. Direct posterior arteries	Peroneal (perforating br.)	Posterior process/body

- Arteries of tarsal canal and tarsal sinus form a primary anastomosis inferior to talar neck that supplies the neck.
- Intraosseous anastomoses allow talus to withstand a less severe vascular injury. Significant vascular injury (e.g., Hawkins type II or III talar neck fracture) often results in AVN.

Plantar view


Proper plantar digital arteries
Common plantar digital arteries
Lumbrical muscles (*cut*)
Deep transverse metatarsal ligament and plantar ligaments (plates)
Interosseous muscles
Plantar
Dorsal
Abductor digiti minimi muscles (*cut*)
Plantar metatarsal arteries
Flexor digiti minimi brevis muscle
Deep plantar arch
Lateral plantar artery (*cut*)
Tuberosity of 5th metatarsal bone
Fibularis (peroneus) longus tendon
Fibularis (peroneus) brevis tendon (*cut*)
Flexor hallucis longus tendon (*cut*)
Anterior perforating branches (to dorsal metatarsal arteries)
Sesamoid bones
Insertion of adductor hallucis and lateral head of flexor hallucis brevis muscles (*cut*)
Insertion of abductor hallucis and medial head of flexor hallucis brevis muscles (*cut*)
Medial origin of flexor hallucis brevis muscle (*cut*)
Deep plantar artery (from dorsalis pedis artery)
Posterior perforating branches (to dorsal metatarsal arteries)
Plantar metatarsal ligaments (between bases of metatarsal bones)
Medial cuneiform bone
Tibialis anterior tendon (*cut*)
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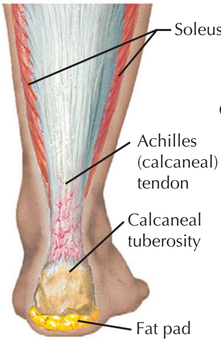
ARTERY	COURSE	BRANCHES	COMMENT/SUPPLY
DORSALIS PEDIS ARTERY			
Direct talar brs.	Directly into talus	None	Supplies head and neck
Medial tarsal	Across tarsals, under EHL tendon	None	Supplies dorsum & medial tarsus
Lateral tarsal	With lateral br., deep peroneal n.	None	Supplies EDB, lateral tarsus
Arcuate	Transversely across metatarsal bases, under EDL tendons	3 dorsal MT arteries (2, 3, 4) 6 dorsal digital arteries 3 posterior perforating arteries 1 dorsal digital artery	Bifurcate at level of MT base Med. & lat. aspects of toes From deep plantar arch Far lateral vessel to small toe
Deep plantar	Descends between 1st & 2nd MTs	Terminates as deep arch	Forms deep plantar arch with terminal branch of lateral plantar artery
1st dorsal metatarsal		Terminal branch of DP 3 dorsal digital arteries	 Medial dorsal hallux & 1st web space
Deep plantar arch	On plantar interosseous muscles in the 4th plantar layer	3 posterior perforating arteries 4 plantar MT arteries 1 common/proper plantar dig. 4 anterior perforating 4 common plantar digital 8 proper plantar digital 1 common/proper plantar	Anastomose with arcuate/dorsal MT Along plantar metatarsal Joins w/terminal br. of med. plantar artery To dorsal metatarsal arteries Continuation after perforators branch Medial, lateral aspects of toes Lateral aspect of small toe

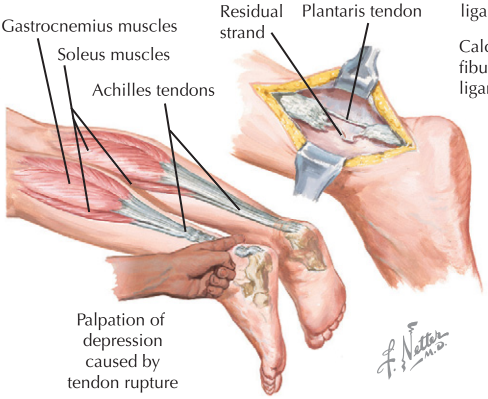
- 10 dorsal digital arteries (8 from the 4 dorsal MT art. plus 2 that branch proximally) do not reach to distal tip of toe.
- 10 proper plantar digital arteries (8 from plantar MT arteries plus 2 that branch proximally) supply the distal tip of toe.
- Each toe has 2 dorsal digital arteries and 2 proper plantar digital arteries.

Achilles Tendinitis


Soleus m.
Achilles (calcaneal) tendon
Calcaneal tuberosity
Fat pad

Achilles tendon with inflammation at insertion into calcaneal tuberosity

Achilles Tendon Rupture


Gastrocnemius muscles
Soleus muscles
Achilles tendons
Residual strand
Plantaris tendon
Palpation of depression caused by tendon rupture
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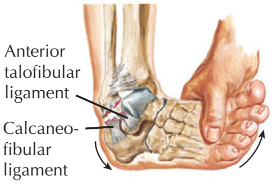
Ankle Sprain

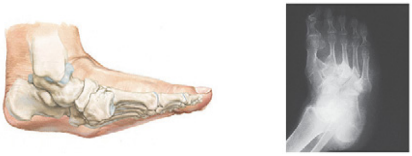

Anterior talofibular ligament
Calcaneo-fibular ligament

Inversion sprain (rupture of calcaneo-fibular and talofibular ligaments)

Arthritis of midfoot

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
ACHILLES TENDINITIS			
• Occurs at or above insertion of Achilles tendon • Microtrauma to insertion	**Hx/PE:** Heel pain, worse with push off; tender to palpation	**XR:** Standing lateral: +/− spur at Achilles insertion **MR:** Fusiform tendon	1. Rest, NSAIDs, heel lift 2. Excise—tendinosus 3. Reconstruct w/FHL tendon
ACHILLES TENDON RUPTURE			
• "Weekend warriors"—middle-aged men/athletics • Occurs with eccentric load	**Hx:** "Pop" sensation **PE:** Defect, + Thompson test	**XR:** Standing AP/lateral; usually normal	1. Casting (in equinus) vs 2. Surgical repair (decrease re-rupture)
ANKLE INSTABILITY			
• Multiple/recurrent sprains • Associated with varus heel • Can be from subtalar joint	**Hx:** Pain and instability **PE:** ATFL/CFL TTP, check for varus heel; + ant. drawer/talar tilt	**XR:** AP/lateral/oblique **Stress:** Drawer and tilt show subluxation	1. Rest, brace PT: strengthen peroneals 2. Surgical reconstruction (Brostrom) if condition persists
ANKLE SPRAIN			
• #1 musculoskeletal injury • Lateral 90%—ATFL only • 60% with CFL, ("high ankle sprain") w/syndesmosis 5% • Inversion #1 mechanism	**Hx:** "Pop," pain, swelling, +/− ability to bear weight **PE:** Edema, ecchymosis, ATFL (CFL) TTP, +/− ant. drawer, talar tilt tests	**XR:** AP, lateral, mortise: Rule out fracture (only if cannot WB, or bony point tenderness)	1. RICE, NSAIDs 2. Immobilize grade III 3. PT & ROM exercises 4. Surgery: severe injury or persistent instability
ARTHRITIS (OA/DJD)			
• Can occur in any joint (ankle, subtalar, midtarsal, midfoot) • Associated with prior trauma, overuse, AVN, inflammatory arthropathy, obesity	**Hx:** Older; pain, +/− previous trauma **PE:** Pain at affected joint, +/− decreased range of motion	**XR:** Weight-bearing images Ankle: AP/lateral/mortise Foot: AP/lateral/oblique Look for classic OA findings	1. NSAIDs, modify activities 2. Orthotics: cup, AFO or double upright Midfoot: steel shank/rocker 3. Fusion or arthroplasty

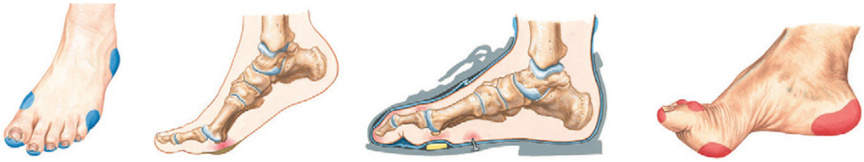
Charcot Foot



Anteroposterior radiograph of Charcot ankle joint

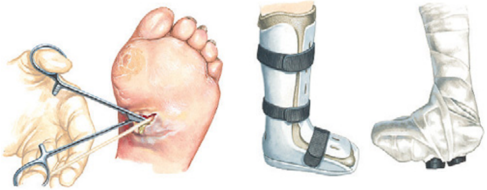
Diabetic Foot

Autonomic and Sensory Neuropathy



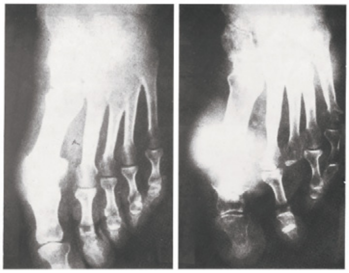
Ulcer

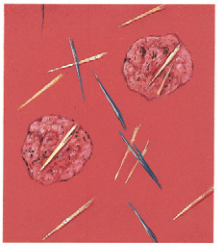
Treatment



DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
CHARCOT NEUROARTHROPATHY			
• End stage of diabetic foot • Decreased sensation—patient cannot detect fracture or dislocation • Multiple injuries, unhealed or malunited leads to joint destruction and deformity	**Hx:** Diabetes. DO NOT complain of pain because they are insensate **PE:** Red, warm, swollen joint, +/− deformity and/or ulcers (may look like infection)	**XR:** AP(WB)/lateral/oblique Findings: osteopenia, fracture, callus, bony prominences, joint destruction **Indium scan:** r/o osteomyelitis	1. Immobilize, skin checks 2. Brace if possible 3. Treat ulcers as needed 4. Bony prominence excision 5. TAL if indicated 6. Selected fusions
CORN			
• Two types ◦ Hard: hyperkeratosis—pressure on bones (5th toe #1) ◦ Soft: interdigit maceration	**Hx/PE:** Tight shoes, pain at lesion site	**XR:** AP/lateral: look for bone spurs/bony prominence	1. Wide toe box shoe 2. Debride callus 3. Pads relieve pressure 4. Excise bony prominence
DIABETIC FOOT			
• Ulcers from pressure & neuropathy (sensory & autonomic); patient doesn't feel pain of lesion • Previous ulcer #1 risk for ulcer • 15% of DM pts. have ulcers • 2° infection can occur • Vascular insufficiency leads to decreased healing potential	**Hx:** NO pain, +/− wound drainage **PE:** Skin changes (e.g., hair loss), diminished/absent pulses, decreased sensation (monofilament tests protective sensation: 5.07 or better), ulcer; erythema, swelling, drainage may be present in infection.	**XR:** Look for osteomyelitis **MR/indium scan:** evaluate for osteomyelitis **Labs:** CBC/CRP (infection) *Ulcer Healing Indicators:* Lymphocytes: >1500 Albumin: >3.5 **ABI:** >0.45 (non-Ca^{++} vessels) Toe pressures: >30 mmHg	1. Prevention: skin care, DM shoes 2. Debride ulcer/callus, total contact casting (TCC) 3. Infection: Superficial: debride, antibiotics; Deep: surgical debridement, IV antibiotics Amputation for severe or persistent cases

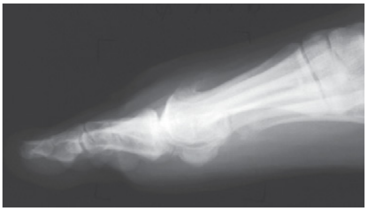
Gout





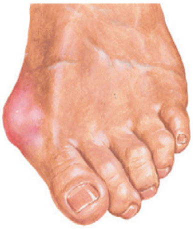
Free and phagocytized monosodium urate crystals in aspirated joint fluid seen on compensated polarized light microscopy

Hallux rigidus

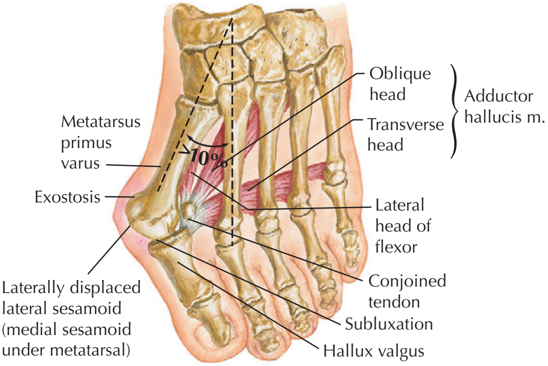


Lateral radiograph showing narrowing of the joint and marked dorsal osteophyte formation

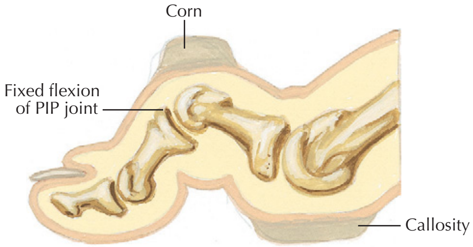
Hallux valgus



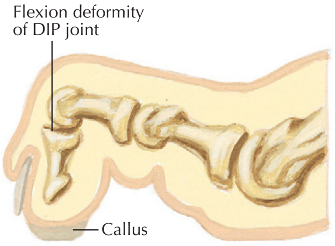
Advanced bunion. Wide (splayed) forefoot with inflamed prominence over 1st metatarsal head. Great toe deviated laterally (hallux valgus), overlaps 2nd toe, and is internally rotated. Other toes also deviated laterally in conformity with great toe. Laterally displaced extensor hallucis longus tendon is apparent


Metatarsus primus varus
10%
Exostosis
Laterally displaced lateral sesamoid (medial sesamoid under metatarsal)
Oblique head
Transverse head
Adductor hallucis m.
Lateral head of flexor
Conjoined tendon
Subluxation
Hallux valgus

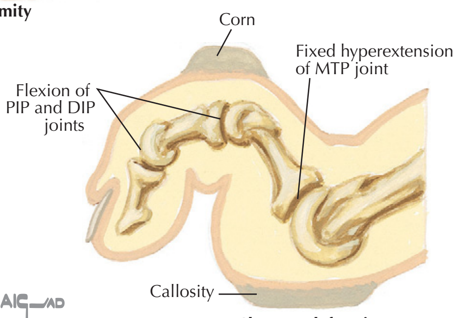
DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
GOUT (PODAGRA)			
• Purine metabolism defect • Monosodium urate, urate crystal deposition create synovitis • 1st MTPJ #1 site	**Hx:** Men; acute & exquisite pain **PE:** Red, swollen toe	**XP:** Erosion on both sides of joint **Labs:** 1. Elevated uric acid; 2. negatively birefringent crystals (in aspirate)	1. NSAIDs/colchicine 2. Rest 3. Allopurinol (prevention) 4. If DJD, fusion
HALLUX RIGIDUS			
• DJD of MTP of great toe • Dorsal metatarsal head osteophyte • Often posttraumatic	**Hx:** Middle age; painful, stiff toe (hallux) **PE:** MTP tender to palpation, decreased ROM	**XR:** standing AP/lateral; dorsal osteophyte or OA findings at 1st MTP	1. NSAID, full length rigid orthosis 2. Cheilectomy 3. Fusion (adv. DJD)
HALLUX VALGUS			
• Deformity: lateral deviation & pronation of hallux, varus 1st MT • Adductor hallucis over pulls hallux • Capsule: medial loose lateral tight • Women (10:1), narrow toe shoes	**Hx:** Pain (worse with shoe wear) **PE:** Valgus deformity/bunion; medial 1st MT head/MTPJ TTP, +/– MTPJ decr. ROM, check for 1st ray hypermobility	**XR:** AP(WB)/lateral/oblique Measure angles: 1. Hallux valgus (nl <15°) 2. Intermetatarsal (nl <9°) 3. Interphalangeal (nl <10°) 4. **DMMA** (nl <15°)	1. Modify shoes: wide toe box 2. Operative: Mild: Chevron or DSTP Severe: Proximal osteotomy/DSTP DJD: 1st MTPJ fusion COMP: recurrence #1



Hammertoe deformity



Mallet toe deformity

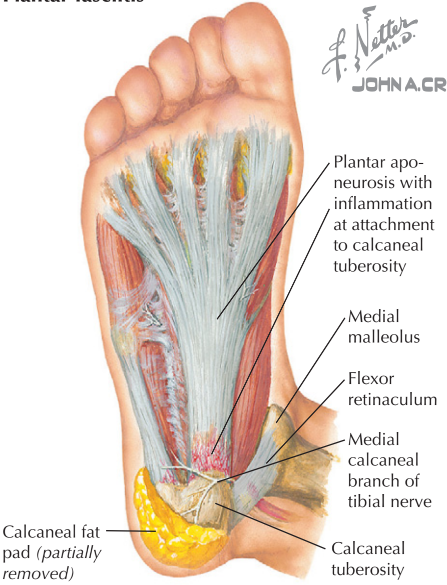

Corn
Fixed hyperextension of MTP joint
Flexion of PIP and DIP joints
Callosity

Claw toe deformity

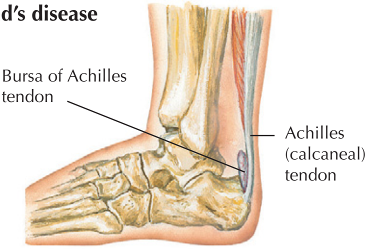
JOHN A.CRAIG MD

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
LESSER TOE DEFORMITIES			
Claw Toes			
• 1° deformity: MTPJ hyperextension (extrinsics overpower weak intrinsic muscles) • 2° deformity: PIP & DIP flexion • Associated with neurologic disease	**Hx:** Toe or plantar foot pain; neuro disease (e.g., DM, CMT) **PE:** Toe deformities, callus on dorsal PIPJ, & plantar MT heads; assess flexibility of deformity	**XR:** AP/lateral/oblique foot; subluxating P1 on MT head **MR:** Spine: r/o neurologic lesion **EMG:** r/o neurologic disease	1. Pads for callus, MT pads or inserts, extra-depth shoes 2. Flexible: FDL to P1 transfer; Fixed: FDL tx, EDB release, lengthen EDL, PIPJ resection
Hammertoes			
• PIPJ flexed w/dorsal callus • MTPJ & DIPJ extended • Assoc. w/tight shoes and long 2nd or 3rd rays (>4mm)	**Hx:** Toe/plantar foot pain **PE:** Toe deformity, callus on dorsal PIPJ, plantar MT head; assess flexibility of deformity	**XR:** WB AP/lateral: Look for joint subluxation Evaluate for long metatarsal	1. Pads, hammertoe braces 2. Flexible: FDL transfer; Fixed: PIPJ resection +/− tx.; extensor release if MTPJ fixed
Mallet Toes			
• Flexion of DIPJ • Assoc. w/long ray in tight shoes & arthritis of DIPJ	**Hx:** Toe pain **PE:** Flexed DIP, dorsal callus over DIPJ	**XR:** AP/lateral/oblique DIPJ deformity	1. Pads, extra-depth shoes 2. FDL tendon release 3. Partial amputation
METATARSALGIA			
• Metatarsal head pain • Etiology: flexor tendinitis, ligament rupture, callus (#1)	**Hx/PE:** Pain under MT head (2nd MT most common)	**XR:** Standing AP/lateral: look for short MT	1. Metatarsal pads 2. Modify shoes 3. Treat underlying cause

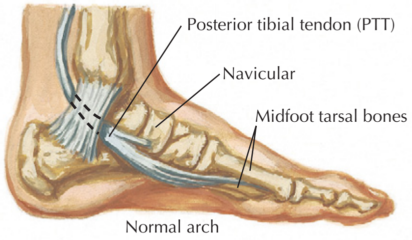
Plantar fasciitis


Plantar aponeurosis with inflammation at attachment to calcaneal tuberosity
Medial malleolus
Flexor retinaculum
Medial calcaneal branch of tibial nerve
Calcaneal fat pad *(partially removed)*
Calcaneal tuberosity
JOHN A.CRAIG

Haglund's disease


Bursa of Achilles tendon
Achilles (calcaneal) tendon

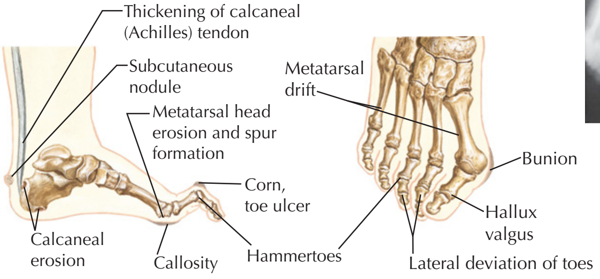
Posterior tibial tendon dysfunction

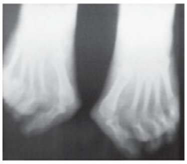

Posterior tibial tendon (PTT)
Navicular
Midfoot tarsal bones
Normal arch

Insertion of posterior tibial tendon extends beyond navicular to all midtarsal bones of foot and is the major supporting structure of midfoot. Injury/attrition at tendon allows arch collapse.

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
MORTON'S NEUROMA (INTERDIGITAL)			
• Fibrosis of irritated nerve • Usually between 2nd and 3rd metatarsals • 5:1 female (shoes)	**Hx:** Pain w/shoes & walking, relief w/rest/no shoes **PE:** MT, web space, TTP, +/– numbness, + compression test	**XR:** Standing AP/lateral: MT heads may be close together	1. Wide toe shoes, steroid injections, MT pads/bars 2. Nerve excision & deep transverse MT lig. release
PLANTAR FASCIITIS			
• Inflammation/degeneration of fascia; female 2:1 • Associated with obesity	**Hx:** AM pain, improves w/ ambulation or stretching **PE:** Medial plantar calcaneus TTP	**XR:** Standing lateral: +/– calcaneal bone spur	1. Stretching, NSAIDs 2. Heel cup 3. Splint (night), casting 4. Partial fascia release
POSTERIOR TIBIALIS TENDON DYSFUNCTION (ACQUIRED FLATFOOT)			
• Failure of post. tib. tendon—foot deformity/loss of arch • Chronic (attrition) or acute (rupture [hx of trauma]) • Assoc. w/obesity and DM • 3 stages: ◦ I: tenosynovitis, no deformity (no pes planus) ◦ II: pes planus, flexible hind foot; no single heel raise ◦ III: rigid hind foot +/–DJD	**Hx:** Med. foot pain, "weakness"; deformity; lat. foot pain in late stages; hx of trauma in some cases **PE:** + pes planus, valgus heel, PT tendon TTP (b/w MM and navicular-hypovascular area), pain with or unable to do single heel raise, + "too many toes sign"	**XR:** **Foot:** AP (WB), lat. oblique; AP: subluxation of talar head; Lat: collapse of long. arch **Ankle:** AP & mortise (WB); look for valgus talar tilt (incompetent deltoid lig.) seen in late stages	**Stage:** I: cast/boot 2-4mo, NSAIDs, custom-molded orthosis II: UCBL/AFO orthosis OR tendon transfer (use FDL) & medial slide calcaneal osteotomy III: Triple arthrodesis +/– TAL (tendoachilles lengthening)
RETROCALCANEAL BURSITIS (HAGLUND'S DISEASE)			
• Bursitis at insertion of Achilles tendon on calcaneus	**Hx:** Pain on posterior heel **PE:** Red, TTP, "pump bump"	**XR:** Standing lateral: spur at Achilles insertion	1. NSAID, heel lift, casting 2. Excise bone/bursa (rare)

Rheumatoid Arthritis


Thickening of calcaneal (Achilles) tendon
Subcutaneous nodule
Metatarsal head erosion and spur formation
Corn, toe ulcer
Calcaneal erosion
Callosity
Hammertoes
Metatarsal drift
Bunion
Hallux valgus
Lateral deviation of toes



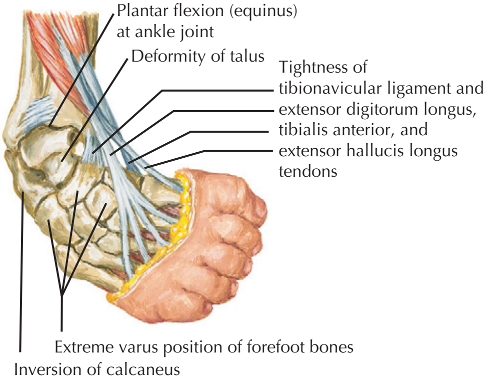
Radiograph reveals severe deformities of forefoot. Hallux valgus, dislocations of metatarsophalangeal joint with lateral deviation of toes. Note also displacement of sesamoids, which results in increased pressure on head of 1st metatarsal

Runner's Foot

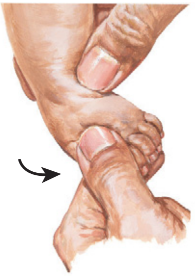
2nd metatarsal stress fracture

DESCRIPTION	Hx & PE	WORKUP/FINDINGS	TREATMENT
RHEUMATOID ARTHRITIS			
• Synovitis is 1° problem • Forefoot: 1st MTPJ has HV, lesser claw toe deformities • Hind foot: PT insufficiency and subtalar instability = valgus heel	**Hx:** Pain, swelling, deformity **PE:** Hallux valgus, claw toes with plantar callus; hind foot in valgus	**XR:** AP(WB)/lateral/oblique: evaluate for joint destruction, osteopenia, joint subluxation, hallux valgus (measure angle) **Labs:** Positive RF, ANA	1 Medical mgmt. of RA 2. Wide toe shoes and orthosis 3. Forefoot: 1st MTPJ fusion, 2-5 lesser toe MT head resection 4. Hind foot: triple arthrodesis
RUNNER'S FOOT			
Multiple etiologies • Medial plantar nerve entrapment • Baxter's nerve (1st br LPN) • Stress fracture	**Hx:** Avid runner, pain **PE:** MPN: medial arch pain; Baxter's n.; plantar/lat. pain Bone TTP (MT, nav., etc)	**XR:** AP/lateral/oblique; usually normal **Bone scan:** evaluate for stress fracture	**Based on etiology:** MPN: release at knot of Henry Baxter's: release abductor hallucis fascia Stress fx: immobilize, rest
SERONEGATIVE SPONDYLOARTHROPATHY (REITER'S, AS, PSORIASIS)			
• Inflammatory arthritides: with symptoms in multiple joints • Types: psoriatic arthritis, Reiter's syndrome, ankylosing spondylitis	**Hx:** Foot pain, any joint **PE:** Evaluate whole foot Psoriatic: sausage digit Reiter/ankyl. spondylitis: Achilles/heel pain, bursitis, plantar fasciitis	**XR:** AP/lateral/oblique Psoriatic: pencil/cup deformity; DIPJ joint erosion; Reiter/AS: +/− enthesiophytes **Labs:** Neg. RF, + HLA-B27	1. Medical management 2. Conservative care of arthritis, tendinitis, bursitis, fascitis 3. Surgical intervention is infrequent
TAILOR'S BUNION (BUNIONETTE)			
• Prominent 5th metatarsal head laterally • Bony exostosis/bursitis	**Hx/PE:** Difficulty fitting shoes, painful lateral 5th metatarsal prominence	**XR:** Standing **AP:** 5th toe medially deviated, MT laterally deviated	1. Pads, wide toe box 2. Mild: chevron osteotomy 3. Severe: MT shelf osteotomy
TARSAL TUNNEL			
• Tibial nerve entrapped by flexor retinaculum or space-occupying lesion (e.g., cyst) in tunnel • Clinical diagnosis	**Hx:** Pain, numbness/tingling **PE:** Pain at tarsal tunnel, +/− sensory changes and Tinel's test	**XR:** AP/lateral; usu. normal **MR:** Mass or lesion in tunnel **EMG:** Confirm clinical diagnosis	1. NSAIDs, steroid inj. 2. Release retinaculum, abductor hallucis fascia, remove any mass (release plantar nerves)
TURF TOE			
• Plantar plate injury (rupture) from MT neck • Hyperextension of 1st MTPJ	**Hx:** Hyperextension, toe (MTP) pain **PE:** Plantar pain, pain with extension (DF), decr. ROM	**XR:** AP/lateral/oblique; usually normal **Bone scan:** r/o stress fx	1. Immobilize, rest, NSAIDs 2. Brace/orthosis to block dorsiflexion during activities

Clubfoot


Plantar flexion (equinus) at ankle joint
Deformity of talus
Tightness of tibionavicular ligament and extensor digitorum longus, tibialis anterior, and extensor hallucis longus tendons
Extreme varus position of forefoot bones
Inversion of calcaneus

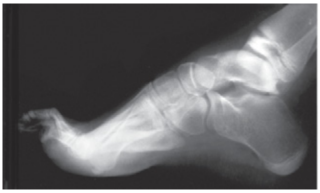
Pathologic changes in congenital clubfoot



Manipulation of foot in step-by-step correction of varus deformity. (Excessive force must be avoided.)

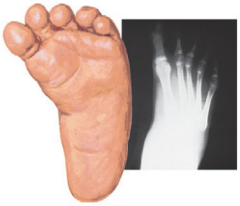
After each stage of manipulation, plaster cast applied to maintain correction

Pes Cavus



Radiograph shows high arch.

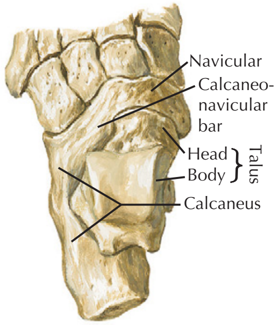
Metatarsus Adductus



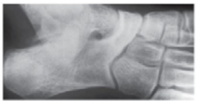
View of sole and radiograph show medial deviation of forefoot

DESCRIPTION	Hx & PE	TREATMENT
CLUBFOOT (TALIPES EQUINOVARUS)		
• Idiopathic, congenital • Boys 2:1, 50% bilateral, 1:1000 • Multifactorial etiology: genetic, environmental • Assoc. w/other conditions • 4 different deformities: **CAVE** • Also seen in neuromuscular disease	**Hx:** Born with deformity **PE:** 4 deformities (mnemonic **CAVE**) **C**avus midfoot, forefoot **A**dductus, subtalar **V**arus, hindfoot **E**quinus **XR:** AP/lateral: "parallelism" of talus & calcaneus Lateral: T-C angle: nl >35º AP: T-C angle: nl 20-40º, <20º in clubfoot	• Ponseti: serial casting + bars ◦ **C**avus: dorsiflex 1st ray ◦ **A**dductus/**V**arus: talar head is the fulcrum for correction ◦ **E**quinus: dorsiflex ankle, TAL • Release if persistent >6-9 m.o. • Neuromuscular: release 6-12mo
PES CAVUS (HIGH ARCH FOOT)		
• High arch due to muscle imbalance in immature foot (TA and peroneus longus); TA weak, PL & PT strong • Ankle flexed: causes pain • Must rule out neuromuscular disease (e.g., Charcot-Marie-Tooth) • May have claw toes	**Hx:** 8-10yr, ankle pain **PE:** Toe walking, tight heel cord, decreased ankle dorsiflexion **XR:** AP/lateral foot and ankle **EMG/NCS:** Test for weakness **MR:** Spine: r/o neuromuscular disease	• Braces/inserts/AFO as needed (used w/mixed results) • Various osteotomies • Tendon transfer and balance
METATARSUS ADDUCTUS		
• Forefoot adduction (varus) • #1 pediatric foot disorder • Assoc. w/intrauterine position or other "packaging" disorders	**Hx:** Parent notices deformity **PE:** "Kidney bean" deformity, negative thigh/foot angle, + intoeing gait	• Most spontaneously resolve with normal development • Serial casting • Abductor hallucis release • Rarely, midfoot osteotomies

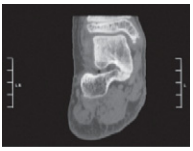
Tarsal Coalition


Navicular
Calcaneo-navicular bar
Head
Body
Talus
Calcaneus

Calcaneonavicular coalition

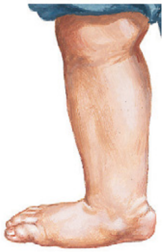


Solid, bony calcaneonavicular coalition evident on oblique radiograph



Medial facet talocalcaneal coalition

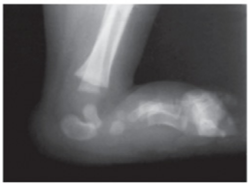
Pes Planovalgus



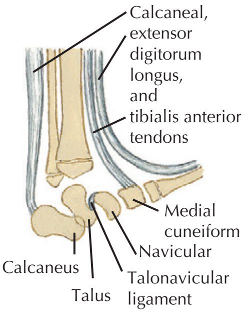
2 year old child, condition more apparent when patient stands.

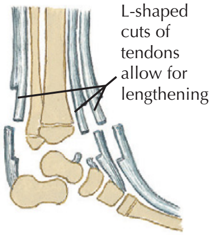
Lateral radiograph of same child's foot

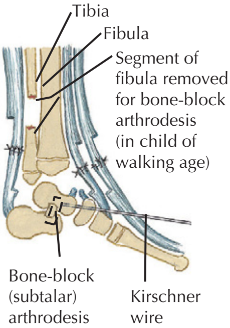
Vertical Talus



Lateral radiograph shows vertical position of talus, plantar flexion of hindfoot, and dorsiflexion of forefoot

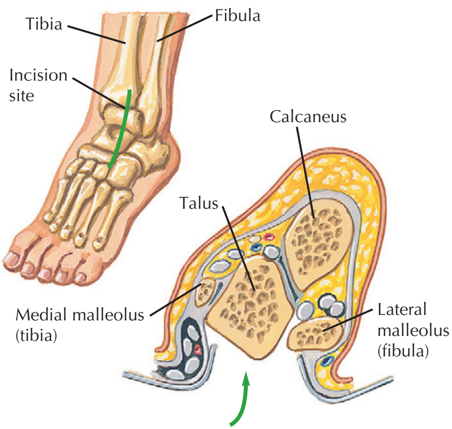

Calcaneal, extensor digitorum longus, and tibialis anterior tendons
Medial cuneiform
Navicular
Calcaneus
Talus
Talonavicular ligament

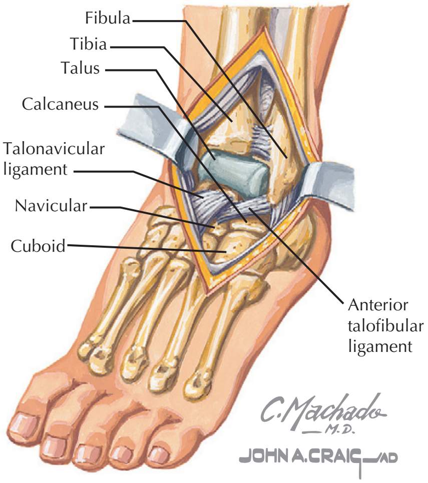

L-shaped cuts of tendons allow for lengthening


Tibia
Fibula
Segment of fibula removed for bone-block arthrodesis (in child of walking age)
Bone-block (subtalar) arthrodesis
Kirschner wire

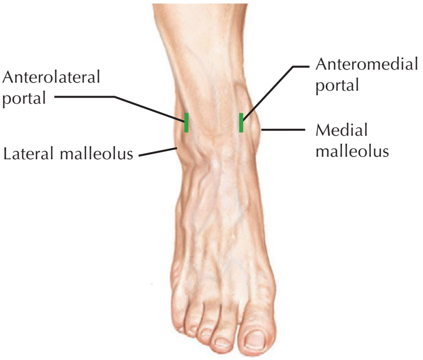
DESCRIPTION	EVALUATION	TREATMENT
FLEXIBLE FLATFOOT		
Pes Planovalgus (Pes Planus)		
• Normal variant • Almost always bilateral • Foot flat only with weight-bearing; forms an arch when non-weight-bearing	**Hx:** Usually asymptomatic, +/– pain w/activity **PE:** Pes planus when WB. NonWB arch reconstitutes; heel goes into varus on heel rise **XR:** Decreased arch, otherwise normal	1. Observation, parental reassurance, no special shoes 2. Arch supports may help if sx mild 3. Calc. osteotomy for persistent pain
RIGID FLATFOOT		
Tarsal Coalition		
• Congenital fusion of 2 tarsal bones • Calcaneonavicular #1 (younger children) • Talocalcaneal (subtalar) #2 (older) • Coalitions can be fibrous, bony, or cartilaginous	**Hx:** Older child/adolescent with insidious onset of pain, worse w/activity **PE:** Rigid flat foot, peroneal spasm **XR:** Anteater sign (calcaneonavicular) **CT:** Best study to identify and measure coalition	1. Cast, orthosis, NSAIDs 2. Persistent or recurrent pain C-N: coalition resection T-C: <50% involved: resection >50% involved: subtalar fusion
Congenital Vertical Talus		
• Talus plantarflexed. Irreducible dorsolateral talonavicular dislocation • Also seen in neuromuscular disorders	**Hx/PE:** Convex/rockerbottom sole, rigid flatfoot (always flat), +/– calcaneovalgus appearance **XR:** PF lateral: talar axis line below cuneiform MT joint	1. Initial casting (in PF) for stretching 2. Complete release at 6-18mo 3. Talectomy in resistant cases

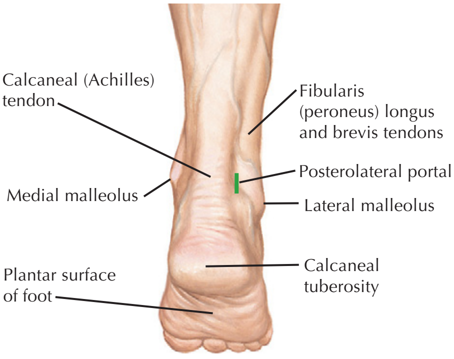
Anterolateral approach to ankle joint


Tibia
Fibula
Incision site
Calcaneus
Talus
Medial malleolus (tibia)
Lateral malleolus (fibula)


Fibula
Tibia
Talus
Calcaneus
Talonavicular ligament
Navicular
Cuboid
Anterior talofibular ligament

Arthroscopy portals


Anterolateral portal
Lateral malleolus
Anteromedial portal
Medial malleolus


Calcaneal (Achilles) tendon
Medial malleolus
Plantar surface of foot
Fibularis (peroneus) longus and brevis tendons
Posterolateral portal
Lateral malleolus
Calcaneal tuberosity

USES	INTERNERVOUS PLANE	DANGERS	COMMENT
ANKLE: ANTEROLATERAL APPROACH			
• Fusions/triple arthrodesis • Fractures (e.g., pilon, talus) • Intertarsal joint access	• Peroneals (superficial peroneal) • EDL (deep peroneal)	• Deep peroneal nerve • Anterior tibial artery	• Can access hind foot • Preserving fat pad (sinus tarsus) helps wound healing
ARTHROSCOPY PORTALS			
Uses: synovectomy, loose body removal, osteochondral lesions, impingement, chondroplasty, some arthrodeses			
Anteromedial	Medial to tibialis anterior (TA) tendon at or just proximal to joint	Saphenous nerve & vein	Least risky portal, should be established first
Anterolateral	Lateral to peroneus tertius tendon at or just proximal to joint	Superficial peroneal nerve	Can establish with needle under direct visualization
Posterolateral	Lateral edge of Achilles tendon 1cm proximal to fibula tip	Sural nerve, lesser saphenous vein	Can establish with needle under direct visualization
Anterocentral, posterocentral, posteromedial portals have been described but are not recommended due to NV risks.			
FASCIOTOMIES			
See page 369			

Abbreviations

A

a.	artery
abd	abduct
abx	antibiotics
AC	acromioclavicular, anterior column
ACJ	acromioclavicular joint
ACL	anterior cruciate ligament
ADI	atlantodens interval
ADM	abductor digiti minimi
AGRAM	arthrogram
AIIS	anterior inferior iliac spine
AIN	anterior interosseous nerve
aka	also known as
ALL	anterior longitudinal ligament
AMBRI	Atraumatic, Multidirectional, Bilateral instability, Rehabilitation, Inferior capsular shift
ANA	antinuclear antibody
ant.	anterior
AP	anteroposterior
APB	abductor pollicis brevis
APC	anterior-posterior compression
APL	abductor pollicis longus
art.	artery
AS	ankylosing spondylitis
ASIS	anterior superior iliac spine
assoc.	associated
ATFL	anterior talofibular ligament
ATP	adenosine triphosphate
AVN	avascular necrosis
AW	anterior wall

B

BG	bone graft
br.	branch
BR	brachioradialis
BTB	bone-tendon-bone
b/w	between

C

CA	cancer
Ca^{++}	ionic calcium
CBC	complete blood cell count
CC	coracoclavicular
CHL	coracohumeral
CL	capitate-lunate joint
CMC	carpometacarpal
CMCJ	carpometacarpal joint
CNS	central nervous system
c/o	complains of
CPK	creatine phosphokinase
CPPD	calcium pyrophosphate dihydrate crystals
CRP	C-reactive protein
CR-PCP	closed reduction, percutaneous pinning
C-spine	cervical spine
CT	carpal tunnel, computed tomography
CTL	capitotriquetral ligament
CTS	carpal tunnel syndrome
cut.	cutaneous

D

º	degree
DAB	dorsal abduct
DDD	degenerative disc disease
decr.	decreased
DF	dorsiflex, dorsiflexion
DIC	dorsal intercarpal ligament
DIO	dorsal interossei
DIPJ	distal interphalangeal joint
DISI	dorsal intercalated segment instability
DJD	degenerative joint disease
DR	distal radius
DRC	dorsal radiocarpal ligament
DRG	dorsal root ganglion
DRUJ	distal radioulnar joint
DVT	deep vein thrombosis
dx	dislocation, diagnosis

E

ECRB	extensor carpi radialis brevis
ECRL	extensor carpi radialis longus
ECU	extensor carpi ulnaris
EDC	extensor digitorum communis
EDL	extensor digitorum longus
EDM	extensor digiti minimi
EHL	extensor hallucis longus
EIA	external iliac artery
EIP	extensor indicis proprius
EMG	electromyogram, electromyography
EPB	extensor pollicis brevis
EPL	extensor pollicis longus

Abbreviations *cont.*

ER	external rotation
esp.	especially
ESR	erythrocyte sedimentation rate
EUA	exam under anesthesia
ext.	extension, extensor

F

FCR	flexor carpi radialis
FCU	flexor carpi ulnaris
FDB	flexor digitorum brevis
FDL	flexor digitorum longus
FDMB	flexor digiti minimi brevis
FDP	flexor digitorum profundus
FDS	flexor digitorum superficialis
FHB	flexor hallucis brevis
FHL	flexor hallucis longus
fix.	fixation
flex.	flexion, flexor
FPB	flexor pollicis brevis
FPL	flexor pollicis longus
fx, fxs	fracture, fractures
fxn	function

G

GAG	glycosaminoglycans
GH	glenohumeral
GI	gastrointestinal
gtr	greater
GU	genitourinary

H

HNP	herniated nucleus pulposus
HO	heterotopic ossification
HTO	high tibial osteotomy
hx	history

I

I&D	incision and drainage, irrigation and debridement
IF	index finger
IJ	internal jugular
IM	intramedullary
incr.	increased
inf.	inferior
inj.	injury
IP	interphalangeal
IR	internal rotation
ITB	iliotibial band
IV	intravenous
IVIG	intravenous immunoglobulin

J

jt	joint

L

LAC	long arm cast
lat.	lateral
LB	loose bodies
LBP	low back pain
LC	lateral compression
LCL	lateral collateral ligament
LE	lower extremity
LFCN	lateral femoral cutaneous nerve
LH	long head
lig.	ligament
LRL	long radiolunate
lsr	lesser
LT	lunotriquetral

M

MC	metacarpal
MCL	medial collateral ligament
MCP	metacarpophalangeal
MCPJ	metacarpophalangeal joint
MDI	multidirectional instability
mech.	mechanism/mechanism of injury
med.	medial
MEN	multiple endocrine neoplasia
MF	middle finger
MPFL	medial patellofemoral ligament
MRI	magnetic resonance imaging
MT	metatarsal
MTPJ	metatarsophalangeal joint
MUA	manipulation under anesthesia
MVA	motor vehicle accident

N

n.	nerve
NCS	nerve conduction study
nl	normal (within normal limits)
NSAID	nonsteroidal anti-inflammatory drug
NV	neurovascular
NWB	non-weight-bearing

O

OA	osteoarthritis
OP	opponens pollicis muscle
ORIF	open reduction, internal fixation

P

PAD	palmar adduct
PC	posterior column
PCL	posterior cruciate ligament
PCP	percutaneous pinning
PE	physical examination
pect.	pectoral
peds	pediatrics/pediatric patients
PF	plantarflex, plantarflexion
PFCN	posterior femoral cutaneous nerve
PFS	patellofemoral syndrome
PG	proteoglycan
PIN	posterior interosseous nerve
PIPJ	proximal interphalangeal joint
PL	palmaris longus
PLC	posterolateral corner complex
PLL	posterior longitudinal ligament
PLRI	posterolateral rotary instability
PMHx	past medical history
PMRI	posteromedial rotary instability
PO	per oral, postoperatively
poll.	pollicus
post.	posterior
PQ	pronator quadratus
prox.	proximal
PRUJ	proximal radioulnar joint
PSIS	posterosuperior iliac spine
PT	posterior tibialis, pronator teres
PTH	parathyroid hormone
pts.	patients
PTTD	posterior tibialis tendon dysfunction
PVNS	pigmented villonodular synovitis
PW	posterior wall

Q

Q	quadriceps

R

RA	rheumatoid arthritis
RAD	radiation absorbed dose
RC	rotator cuff
RCL	radioscaphocapitate ligament
RF	rheumatoid factor, ring finger
RH	radial head
RICE	rest, ice, compression, and elevation
r/o	rule out
ROM	range of motion
RSC	radioscaphocapitate
RSD	reflex sympathetic dystrophy
RSL	radioscapholunate ligament
RTL	radiolunotriquetral ligament

S

SAC	short arm cast
SC	scaphocapitate, sternoclavicular
SCM	sternocleidomastoid
SF	small finger
SFA	superficial femoral artery
SGN	superior gluteal nerve
SH	short head
SI	sacroiliac
SIJ	sacroiliac joint
SL	scapholunate
SLAC	scapholunate advanced collapse
SLAP	superior labrum anterior/posterior
SLNWC	short leg non weightbearing cast
SPN	superficial peroneal nerve
sRL	short radiolunate
SS	supraspinatus
STT	scaphotrapeziotrapezoid
sup.	superior
sx	symptom
synd.	syndrome

T

TA	tibialis anterior
TAL	transverse acetabular ligament, transverse atlantal ligament
TC	triquetrocapitate
TCL	transverse carpal ligament
Td	tetanus and diphtheria toxoid
TFC	triangular fibrocartilage
TFCC	triangular fibrocartilage complex
TFL	tensor fascia lata
TH	triquetrohamate
THA	total hip arthroplasty
THC	triquetrohamocapitate
TIG	tetanus immunoglobulin
TKA	total knee arthroplasty
TLSO	thoracolumbosacral orthosis
TP	tibialis posterior
TTP	tenderness to palpation
TUBS	Traumatic, Unilateral instability, Bankart lesion, Surgery
tx	treatment

Abbreviations *cont.*

U

UE	upper extremity
UL	ulnolunate
UMN	upper motor neuron
usu.	usually
UT	ulnotriquetral

V

VIO	volar interosseus
VISI	volar intercalated segment instability
VMO	vastus medialis obliquus

W

w/	with
WB	weight bearing
WBAT	weight bear as tolerated
WBC	white blood cell count

X-Z

XR	x-ray
XRT	radiation therapy
y.o.	year old

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